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Supplementary appendix

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The Impact of Expanding Opioid Agonist Therapies on HIV epidemic and mortality in Ukraine: a Modeling study

Supplementary Appendix

Jiale Tan, Frederick L. Altice, Lynn Madden, Alexei Zelenev

1. OAT retention optimization model:

1.0 OAT Dosage and retention in Care

In order to model the relationship between dosage and retention in OAT, we fit several parametric survival models, in which the duration outcome was measured as “days on OAT”.

The data from analyses was taken from the Syrex database containing individual patients’ records on the duration of OAT treatment from 2011-2016 at each of the 179 sites in the entire country. The sample size analyzed consisted of 17,602 unique individuals with more than 20,400 MMT treatment episodes. Syrex also contained information of the recorded “average” dosage of OAT every three months that was prescribed during the treatment episode. When fitting several different parametric survival models, we found that exponential distribution provided a better fit relative to the Weibull distribution, the Loglogistic and the Log-Normal Distributions based on Cox-Snell’s residuals. The average duration of OAT Treatment was found to be statistically different between dosage categories which were grouped by quantiles at 1% level. We also considered smaller grouping categories and found that the OAT hazard rates were statistically similar within the larger dosage categories.

Table S1: Association between dosage and retention in OAT: Survival Regression Analysis

Outcome: Duration in OAT	Hazards Ratio	Std. Err.	P-values	95% CI	
<40 mg	Referent				
40-60 mg	1.31	0.12	0.00	1.10	1.57
61-99 mg	0.81	0.06	0.01	0.70	0.95
>=100 mg	0.50	0.04	0.00	0.42	0.58
_cons	0.00	0.00	0.00	0.00	0.00

Table S2. Average Duration of Treatment and Attrition Probability by Dosage Category

Dosage Category	N (%)	Average Duration in Treatment Based on Survival Analysis Extended Mean (months)	Probability of Monthly Attrition Under Constant Hazard Assumption
<40 mg	3382 (22.1%)	32.2	0.031
40-60 mg	4206 (27.5%)	43.2	0.023
61-99 mg	3636 (23.7%)	53.2	0.019
≥100 mg	4089 (26.7%)	79.4	0.013

1.1 Model description and structure

The objective of the constrained linear optimization method is to find the *maximum* number of *expected* patients that could be enrolled into OAT treatment given the current resource constraint (i.e. total procured OAT). The *expected* patients comes from two different resources: 1. enrolled patients who are willing to stay on OAT; 2. new patients. In our model's formulation, each region *r* is assumed to have a "chief executive" in charge of making two decisions at each time point *t*: whether to admit A_j patient from a set of J patients into a specific OAT program, a dose to give to the newly admitted patients (d_j), as well as the MMT dose, d_i that each enrolled participant (P_i) receives:

$$\max \ \mathbf{E}[(\textstyle\sum_{i,j}\sum_{r=1}^{23}\sum_{t=1}^{365}\mathrm{P}_{i,r,t}(\mathrm{d}_{i,r,t}) + \mathrm{A}_{j,r,t+1}\ )] \tag{S1}$$

Where

$$\mathrm{A}_{j,r,t+1} = \begin{cases} 1, & \text{if patient j is admitted to OAT in a region } r \text{ at time } t+1 \\ 0, & \text{if patient j is NOT admitted to OAT in a region } r \text{ at time } t+1 \end{cases} \tag{S2}$$

$$P_{i,r,t}(\mathrm{d}_{i,r,t}) = \begin{cases} 1, & \text{enrolled patient i stays in OAT in region } r \text{ and time } t \\ 0, & \text{enrolled patient i is not in OAT in region } r \text{ and time } t \end{cases} \tag{S3}$$

Subject to the following constraints for each patient i and oblast r at any time t:

(i) Participation: $$\textstyle\sum_i \mathrm{P}(\mathrm{d}_{i,r,t+1}) = \max(\sum_i \mathrm{P}(\mathrm{d}_{i,r,t}) - \sum_i \mathrm{P}(\mathrm{d}_{i,r,t}) \cdot f_a(Q_{i,r,t}|\mathrm{d}_{i,r,t}), 0) \tag{S4}$$

(ii) Resource: $$\textstyle\sum_i \sum_{t=1}^{365}(\mathrm{d}_{i,r,t}) \le K_r \ \text{ for each oblast r} \tag{S5}$$

(iii) Individual Dosage: $$22 \le \mathrm{d}_{i,r,t} \le 101 \ \ \& \ \ \mathrm{d}_{i,r,t} \le \mathrm{d}_{i,r,t+1} \tag{S6}$$

For the linear optimization model, we assumed a constant hazard rate for attrition when calculating the probability that the enrolled patients exit OAT (f_a):

$$f_a\left(Q_{i,r,t}|\mathrm{d}_{i,r,t}\right) = \begin{cases} 0.031 & \mathrm{d}_{i,r,t} < 40\ mg \\ 0.023 & 40\ mg \le \mathrm{d}_{i,r,t} \le 60\ mg \\ 0.019 & 60\ mg < \mathrm{d}_{i,r,t} < 100\ mg \\ 0.013, & 100\ mg \le \mathrm{d}_{i,r,t} \end{cases} \tag{S7}$$

Table S3: Summary of Operational Efficiency among OAT programs in Regions in 2016

Region	**Number of Sites**	**Average Occupancy**	**Retention %**	**Median Time to Fill 1 slot, Days (10th, 90th pctl)**	**OAT Coverage % In 2016**
Zakarpattia	2	25	82.6	28.5 (11.0,99.0)	1.0
Zhytomyr	5	289	77.4	2.5 (1.0 ,7.0)	9.0
Chernivtsi	1	57	79.4	11.1 (1.3,35.5)	1.6
Ivano-Frankivsk	11	229	85.8	4.0 (1,10)	6.0
Ternopil	3	77	82.5	7.5 (1.0,29.2)	1.9
Rivne	4	145	89.6	3.0 (1.0,38.5)	3.1
Vinnytsa	16	304	85.2	4.0 (1,9.6)	5.3
Volyn	7	132	80.9	5.0 (1.0,16)	2.0
Chernihiv	4	177	87.1	4.0 (1.0,12.3)	2.6
Kyiv	2	156	86.9	7.0 (2.5,30)	1.9
Poltava	12	585	82.5	2.2 (0.6,6.5)	7.1
Khmelnytskyi	10	312	77.1	3.0 (1.0,9.9)	3.6
Kirovohrad	4	273	88.7	3.5 (1,13.8)	3.1
Kherson	6	215	81.7	5.0 (1.2,13.4)	2.2
Lviv	6	241	83.4	5.0 (2.0,14.8)	2.2
Cherkasy	8	165	79.3	7.0 (1.0,18.4)	1.4
Mykolaiv	13	664	78.3	1.1 (0.5,6.0)	5.8
Zaporizhia	5	274	86.2	5.0 (1.0,15.6)	2.4
Sumy	8	330	83.6	2 (1.0, 7.0)	2.7
Kharkiv	10	292	86.8	3.0 (1.0,12.8)	1.9
Kyiv (city)	6	657	83.8	1.0 (0.3, 3.5)	1.9
Odesa	4	272	89.2	3.0 (1, 11.6)	0.7
Dnipro	24	1391	76.3	1.0 (0.3, 4.0)	3.4
Ukraine (Total)	**171**	**7,262**	**83.2**	**0.3 (0.1, 0.81)**	**2.7**

2. HIV transmission compartment model:

2.1 Model description

We developed a dynamic, deterministic compartmental model of HIV transmission in Ukraine's population. Figure S1 contains the schematic for the HIV transmission model. In the compartmental model we stratified the population into three mutually exclusive groups: heterosexual men (HM), heterosexual women (HW) and men who have sex with men (MSM). The individuals in the three groups enter PWID population through initiation of injection and exit through cessation or death. Entry into OAT among PWID was associated with reduced number of injections as well as reduced risk of mortality (Table S1), while exit from OAT was associated with higher frequency of injection behavior and greater mortality risk. The rates of HIV transmission varied across different population compartments, as susceptible individuals (S) could become infected with the HIV virus through sexual contact, as well as sharing of paraphernalia with HIV positive individuals. In the model we assumed proportional mixing of the populations.

2.2 Model parameterization

Main Data Sources:
Statistics on the population size, population growth and mortality were taken from the Ukranian Census, which compiled the data for each region. Data on the size of PWID, as well as HIV prevalence was taken from data from reports published by the Alliance for Public Health in Ukraine, that conducts an Integrated Bio-behavioral Survey (IBBS), which is conducted every other year.

ExMAT Data
From January 2014 to March 2015, self-administered surveys with linked HIV and HCV testing was conducted in five large cities: Kyiv (Kiev), Odesa (Odessa), Mykolaiv (Nikolaev), Dnipro (Dnipropetrovsk), and Lviv (Lvov). Recruitment occurred sequentially (approximately 60–90 days per city) between 2014 and 2015. The sample was stratified by three groups of PWID: 1) currently on OAT; 2) previously on OAT; and 3) never on OAT. The overall objective of the study was to understand drug use behavior, health outcomes, risk factors, and barriers and facilitators of accessing OAT treatment among PWID in Ukraine. The eligibility criteria required that the study participants be 18 or older, and meet ICD-10 criteria for opioid dependence, and either reside or work in the city, where sampling took place. Study participants who were currently or previously on OAT were randomly selected from client lists obtained from OAT sites in each city and invited by outreach workers to participate in the study. Respondent Driven Sampling (RDS) was used primarily to recruit clients who had never been on OAT, but also included individuals who has OAT experience.[1-5] The study was approved at Institutional Review boards at Yale University and the Gromashevskiy Institute at the National Academy of Medical Sciences.

SyrEX Database
SyrEx is a database management system developed and maintained by the Alliance for Public Health in Ukraine. The database contains information on treatment episodes, as well as average dosing, for patients participating in OAT from 2009-2016 in 28 regions in Ukraine. The total sample size consists of more than 20,000 patient records, which have been de-identified. The data set was used for analyzing the association between retention in OAT and dosing, as well as in the calculation of mortality rates among HIV+ and HIV- PWID on OAT, and the rates of viral suppression. In several instances, we used multiple imputations to estimate mortality rates among HIV+ PWID on OAT in Zakarpattia, Sumy and Ternopil regions, and the mortality rates among HIV- PWID on OAT in Zakarapattia and Chernigiv due to lack of data stemming from small sample sizes [6].

Figure S1: HIV transmission compartment model schematics

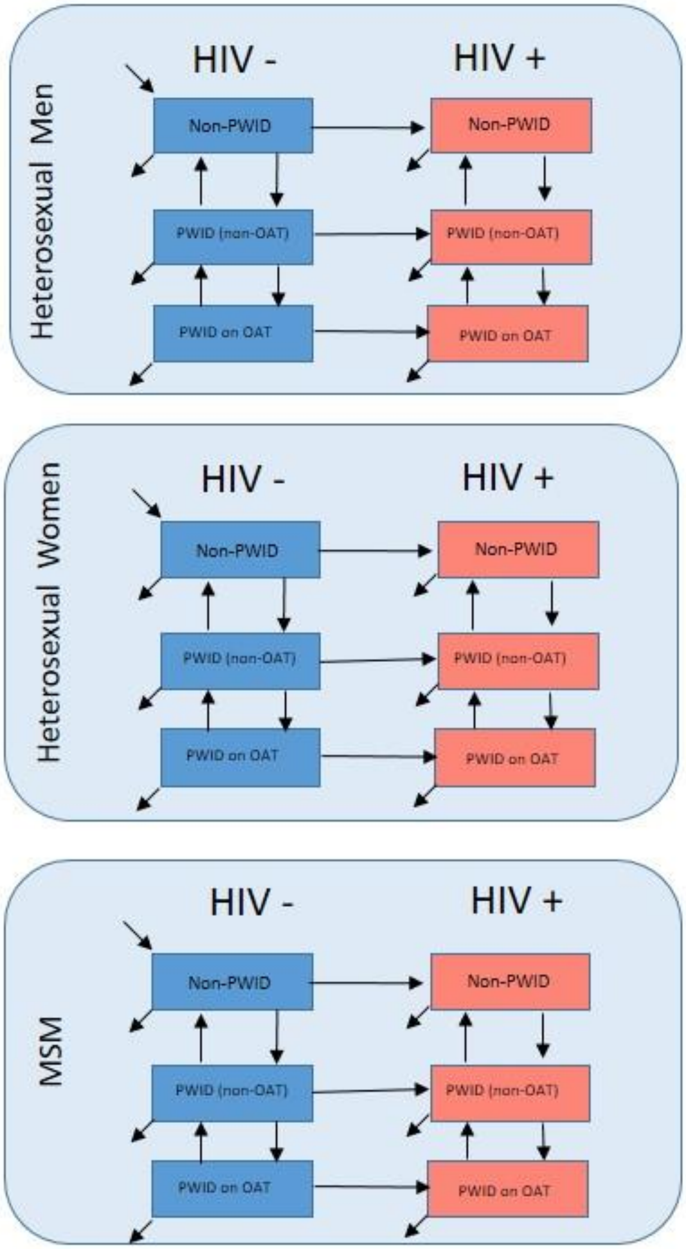


Table S4: HIV transmission compartment model parameters

Parameters	Definition	Median Value (Regional Range)	Distribution	Source
d_1	Mortality rate per year among non-PWID, HIV-	0.011 (0.009,0.012)	LogNormal	Ukrainian Census [7]
d_2	Mortality rate per year among non-PWID, HIV+	0.021 (0.008 — 0.037)	LogNormal	Ukrainian Center for Public Health [8]
d_3	Mortality rate per year among non-OAT PWID, HIV -	0.061 (0.012-0.18)	Calculated	Calculation Based on Sordo et al[9]
d_4	Mortality rate per year among non-OAT PWID, HIV+	0.14 (0.04-0.26)	Calculated	Calculation Based on Sordo et al[9]
d_5	Mortality rate per year among OAT PWID, HIV -	0.019 (0.0036-0.057)	LogNormal	Syrex database (Description in the Appendix)
d_6	Mortality rate per year among OAT PWID, HIV+	0.05 (0.0137-0.083)	LogNormal	Syrex database
mrr_{oat}	Mortality Risk Ratio: PWID on OAT vs Non-OAT	3.2 (2.6-3.86)	Uniform	9
u_1	Rate of Entry into drug injection group among HIV-	0.00062 (0.0005-0.00073)	-	Calibrated to fit the model
u_3	Entry rate into drug injection among HIV+	0.0005 (0.000376-0.0006)	-	Calibrated to fit the model
u_2	OAT Entry rate among HIV- PWID	0.00987 (0.0001-0.044)	-	Calibrated to fit the model
u_4	OAT entry among HIV+ PWID	0.0055 (0.00001-0.018)	-	Calibrated to fit the model
α	Average number of sexual act frequency per month	6.27** (1-11.2)	Poisson	10
f	Probability of unprotected sex (per sexual act)	0.47 (0.39-0.59)	Varied to fit the model	Calibrated to fit the model
β_1	Average number of injections per day among PWID not on OAT	0.90 (0.3 — 1.31)	Varied to fit the model	Calibrated to fit the model
β_2	Average number of injections per day among PWID on OAT	0.12 (0.095 — 0.14)	Beta	ExMAT data[11] (Description in the Appendix)
f_1	Probability of sharing needles among PWID not on OAT	0.16 (0.04 — 0.28)	-	Varied to fit the model
f_2	Probability of sharing needles among PWID on OAT	0.009 (0.0006-0.02)	Beta	ExMAT data[11] (Description in the Appendix)
σ_{MSM}	Probability of HIV infection per unprotected anal sex act among MSM	0.016 (0.0029-0.0402)	None	Calibrated to fit the model
σ_W	Probability of HIV infection per unprotected receptive vaginal sexual act	0.0027 (0.0003-0.0049)	None	Calibrated to fit the model
σ_M	Probability of HIV Infection per unprotected insertive vaginal sexual act	0.0028 (0.0001-0.0050)	None	Calibrated to fit the model
σ_I	Probability of HIV infection per injection among PWID	0.0037 (0.0013-0.0075)	None	Calibrated to fit the model
δ	Entry Rate into Susceptible	0.01	-	Calibrated to fit the model
v_{oat}	Probability of Viral Suppression among HIV+ PWID on OAT	0.446 (0.108—0.99)	LogNormal	SyReX (Description in the Appendix)
$v_{Non-oat}$	Proportion of HIV+ PWID who attain viral suppression among non-OAT PWID on ART	0.668 (0.4875- 0.7707)	LogNormal	Ukraine's Ministry of Health [12]
R_{ART}	Proportion of PWID receiving ART among Non-OAT, HIV+ PWID	0.562 (0.4794, 0.7261)	LogNormal	Ukraine's Ministry of Health [12]
T_{HIV}	Proportion of HIV+ that are aware of infection status	0.56	None	UNAIDS[13]

Note: MSM- Men who have sex with men, PWID –people who inject drugs, OAT - opioid agonist therapies, ART – antiretroviral therapy
**Converted to a Number of times per day in the model

2.3 Model Equations

The total size of susceptible (S) and infected (I) compartments in each population group can be can be expressed as a sum of non-PWID, PWID on OAT, and PWID not on OAT:

$$S_{\mathrm{MSM}} = S_{\mathrm{MSM,NONPWID}} + S_{\mathrm{MSM,PWID,NONOAT}} + S_{\mathrm{MSM,PWID,OAT}} \tag{S8}$$

$$I_{\mathrm{MSM}} = I_{\mathrm{MSM,NONPWID}} + I_{\mathrm{MSM,PWID,NONOAT}} + I_{\mathrm{MSM,PWID,OAT}} \tag{S9}$$

$$I_{\mathrm{MSM,NONOAT}} = I_{\mathrm{MSM,NONPWID}} + I_{\mathrm{MSM,PWID,NONOAT}} \tag{S10}$$

$$S_{\mathrm{HM}} = S_{\mathrm{HM,NONPWID}} + S_{\mathrm{HM,PWID,NONOAT}} + S_{\mathrm{HM,PWID,OAT}} \tag{S11}$$

$$I_{\mathrm{HM}} = I_{\mathrm{HM,NONPWID}} + I_{\mathrm{HM,PWID,NONOAT}} + I_{\mathrm{HM,PWID,OAT}} \tag{S12}$$

$$I_{\mathrm{HM,NONOAT}} = I_{\mathrm{HM,NONPWID}} + I_{\mathrm{HM,PWID,NONOAT}} \tag{S13}$$

$$S_{\mathrm{HW}} = S_{\mathrm{HW,NONPWID}} + S_{\mathrm{HW,PWID,NONOAT}} + S_{\mathrm{HW,PWID,OAT}} \tag{S14}$$

$$I_{\mathrm{HW}} = I_{\mathrm{HW,NONPWID}} + I_{\mathrm{HW,PWID,NONOAT}} + I_{\mathrm{HW,PWID,OAT}} \tag{S15}$$

$$I_{\mathrm{HW,NONOAT}} = I_{\mathrm{HW,NONPWID}} + I_{\mathrm{HW,PWID,NONOAT}} \tag{S16}$$

$$S_{\mathrm{PWID}} = S_{\mathrm{MSM,PWID,NONOAT}} + S_{\mathrm{MSM,PWID,OAT}} + S_{\mathrm{HM,PWID,NONOAT}} + S_{\mathrm{HM,PWID,OAT}} + S_{\mathrm{HW,PWID,NONOAT}} + S_{\mathrm{HW,PWID,OAT}} \tag{S17}$$

$$I_{\mathrm{PWID}} = I_{\mathrm{MSM,PWID,NONOAT}} + I_{\mathrm{MSM,PWID,OAT}} + I_{\mathrm{HM,PWID,NONOAT}} + I_{\mathrm{HM,PWID,OAT}} + I_{\mathrm{HW,PWID,NONOAT}} + I_{\mathrm{HW,PWID,OAT}} \tag{S18}$$

$$I_{\mathrm{PWID,NONOAT}} = I_{\mathrm{MSM,PWID,NONOAT}} + I_{\mathrm{HM,PWID,NONOAT}} + I_{\mathrm{HW,PWID,NONOAT}} \tag{S19}$$

$$I_{\mathrm{PWID,OAT}} = I_{\mathrm{MSM,PWID,OAT}} + I_{\mathrm{HM,PWID,OAT}} + I_{\mathrm{HW,PWID,OAT}} \tag{S20}$$

Equations modeling transmission:

$$t_{\mathrm{MSM,NONPWID}} = 1 - \left((1-\mathrm{f}) + \mathrm{f} \cdot \frac{S_{\mathrm{MSM}} + I_{\mathrm{MSM,NONOAT}} \cdot \mathrm{T}_{HIV} \cdot \mathrm{R}_{ART} \cdot v_{non-oat} + I_{\mathrm{MSM,PWID,OAT}} \cdot v_{oat}}{S_{\mathrm{MSM}} + I_{\mathrm{MSM}}} + \mathrm{f} \cdot \frac{I_{\mathrm{MSM}} - I_{\mathrm{MSM,NONOAT}} \cdot \mathrm{T}_{HIV} \cdot \mathrm{R}_{ART} \cdot v_{non-oat} - I_{\mathrm{MSM,PWID,OAT}} \cdot v_{oat}}{S_{\mathrm{MSM}} + I_{\mathrm{MSM}}} \cdot (1-\sigma_{MSM})\right)^{365\alpha} \tag{S21}$$

$$t_{\mathrm{MSM,PWID,NONOAT}} = 1-\left((1-\mathrm{f}_1)+\mathrm{f}_1\cdot\frac{S_{\mathrm{PWID}}+I_{\mathrm{PWID,OAT}}\cdot v_{oat}+I_{\mathrm{PWID,NONOAT}}\cdot \mathrm{T}_{HIV}\cdot \mathrm{R}_{ART}\cdot v_{non-oat}}{S_{\mathrm{PWID}}+I_{\mathrm{PWID}}}+\mathrm{f}_1\cdot\frac{I_{\mathrm{PWID}}-I_{\mathrm{PWID,OAT}}\cdot v_{oat}-I_{\mathrm{PWID,NONOAT}}\cdot \mathrm{T}_{HIV}\cdot \mathrm{R}_{ART}\cdot v_{Non-oat}}{S_{\mathrm{PWID}}+I_{\mathrm{PWID}}}\cdot(1-\sigma_I)\right)^{365\beta_1}+t_{\mathrm{MSM,NONPWID}} \tag{S22}$$

$$t_{\mathrm{MSM,PWID,OAT}} = 1-\left((1-\mathrm{f}_2)+\mathrm{f}_2\cdot\frac{S_{\mathrm{PWID}}+I_{\mathrm{PWID,OAT}}\cdot v_{oat}+I_{\mathrm{PWID,NONOAT}}\cdot \mathrm{T}_{HIV}\cdot \mathrm{R}_{ART}\cdot v_{Non-oat}}{S_{\mathrm{PWID}}+I_{\mathrm{PWID}}}+\mathrm{f}_2\cdot\frac{I_{\mathrm{PWID}}-I_{\mathrm{PWID,OAT}}\cdot v_{oat}-I_{\mathrm{PWID,NONOAT}}\cdot \mathrm{T}_{HIV}\cdot \mathrm{R}_{ART}\cdot v_{Non-oat}}{S_{\mathrm{PWID}}+I_{\mathrm{PWID}}}\cdot(1-\sigma_I)\right)^{365\beta_2}+t_{\mathrm{MSM,NONPWID}} \tag{S23}$$

$$t_{\mathrm{HM,NONPWID}} = 1-\left((1-\mathrm{f})+\mathrm{f}\cdot\frac{S_{\mathrm{HW}}+I_{\mathrm{HW,NONOAT}}\cdot \mathrm{T}_{HIV}\cdot \mathrm{R}_{ART}\cdot v_{Non-oat}+I_{\mathrm{HW,PWID,OAT}}\cdot v_{oat}}{S_{\mathrm{HW}}+I_{\mathrm{HW}}}+\mathrm{f}\cdot\frac{I_{\mathrm{HW}}-I_{\mathrm{HW,NONOAT}}\cdot \mathrm{T}_{HIV}\cdot \mathrm{R}_{ART}\cdot v_{Non-oat}-I_{\mathrm{HW,PWID,OAT}}\cdot v_{oat}}{S_{\mathrm{HW}}+I_{\mathrm{HW}}}\cdot(1-\sigma_M)\right)^{365\alpha} \tag{S24}$$

$$t_{\mathrm{HM,PWID,NONOAT}} = 1-\left((1-\mathrm{f}_1)+\mathrm{f}_1\cdot\frac{S_{\mathrm{PWID}}+I_{\mathrm{PWID,OAT}}\cdot v_{oat}+I_{\mathrm{PWID,NONOAT}}\cdot \mathrm{T}_{HIV}\cdot \mathrm{R}_{ART}\cdot v_{Non-oat}}{S_{\mathrm{PWID}}+I_{\mathrm{PWID}}}+\mathrm{f}_1\cdot\frac{I_{\mathrm{PWID}}-I_{\mathrm{PWID,OAT}}\cdot r_{ARTS}-I_{\mathrm{PWID,NONOAT}}\cdot \mathrm{T}_{HIV}\cdot \mathrm{R}_{ART}\cdot v_{Non-oat}}{S_{\mathrm{PWID}}+I_{\mathrm{PWID}}}\cdot(1-\sigma_I)\right)^{365\beta_1}+t_{\mathrm{HM,NONPWID}} \tag{S25}$$

$$t_{\mathrm{HM,PWID,OAT}} = 1-\left((1-\mathrm{f}_2)+\mathrm{f}_2\cdot\frac{S_{\mathrm{PWID}}+I_{\mathrm{PWID,OAT}}\cdot v_{oat}+I_{\mathrm{PWID,NONOAT}}\cdot \mathrm{T}_{HIV}\cdot \mathrm{R}_{ART}\cdot r_{ARTSNON}}{S_{\mathrm{PWID}}+I_{\mathrm{PWID}}}+\mathrm{f}_2\cdot\frac{I_{\mathrm{PWID}}-I_{\mathrm{PWID,OAT}}\cdot r_{ARTS}-I_{\mathrm{PWID,NONOAT}}\cdot \mathrm{T}_{HIV}\cdot \mathrm{R}_{ART}\cdot v_{Non-oat}}{S_{\mathrm{PWID}}+I_{\mathrm{PWID}}}\cdot(1-\sigma_I)\right)^{365\beta_2}+t_{\mathrm{HM,NONPWID}} \tag{S26}$$

$$t_{\mathrm{HW,NONPWID}} = 1-\left((1-\mathrm{f})+\mathrm{f}\cdot\frac{S_{\mathrm{HM}}+I_{\mathrm{HM,NONOAT}}\cdot \mathrm{T}_{HIV}\cdot \mathrm{R}_{ART}\cdot v_{Non-oat}+I_{\mathrm{HM,PWID,OAT}}\cdot v_{oat}}{S_{\mathrm{HM}}+I_{\mathrm{HM}}}+\mathrm{f}\cdot\frac{I_{\mathrm{HM}}-I_{\mathrm{HM,NONOAT}}\cdot \mathrm{T}_{HIV}\cdot \mathrm{R}_{ART}\cdot v_{Non-oat}-I_{\mathrm{HM,PWID,OAT}}\cdot v_{oat}}{S_{\mathrm{HM}}+I_{\mathrm{HM}}}\cdot(1-\sigma_W)\right)^{365\alpha} \tag{S27}$$

$$t_{\mathrm{HW,PWID,NONOAT}} = 1-\left((1-\mathrm{f}_1)+\mathrm{f}_1\cdot\frac{S_{\mathrm{PWID}}+I_{\mathrm{PWID,OAT}}\cdot v_{oat}+I_{\mathrm{PWID,NONOAT}}\cdot \mathrm{T}_{HIV}\cdot \mathrm{R}_{ART}\cdot v_{Non-oat}}{S_{\mathrm{PWID}}+I_{\mathrm{PWID}}}+\mathrm{f}_1\cdot\frac{I_{\mathrm{PWID}}-I_{\mathrm{PWID,OAT}}\cdot v_{oat}-I_{\mathrm{PWID,NONOAT}}\cdot \mathrm{T}_{HIV}\cdot \mathrm{R}_{ART}\cdot v_{Non-oat}}{S_{\mathrm{PWID}}+I_{\mathrm{PWID}}}\cdot(1-\sigma_I)\right)^{365\beta_1}+t_{\mathrm{HW,NONPWID}} \tag{S28}$$

$$t_{\text{HW,PWID,OAT}} = 1 - ((1-\text{f}_2) + \text{f}_2 \cdot \frac{S_{\text{PWID}} + I_{\text{PWID,OAT}} \cdot v_{oat} + I_{\text{PWID,NONOAT}} \cdot \text{T}_{HIV} \cdot \text{R}_{ART} \cdot v_{Non-oat}}{S_{\text{PWID}} + I_{\text{PWID}}} + \text{f}_2 \cdot \frac{I_{\text{PWID}} - I_{\text{PWID,OAT}} \cdot v_{oat} - I_{\text{PWID,NONOAT}} \cdot \text{T}_{HIV} \cdot \text{R}_{ART} \cdot v_{Non-oat}}{S_{\text{PWID}} + I_{\text{PWID}}} \cdot (1-\sigma_I))^{365\beta_2} + t_{\text{HW,NONPWID}} \tag{S29}$$

Transition equations:

$$\frac{dS_{\text{MSM,NONPWID}}}{dt} = \delta P_1 - S_{\text{MSM,NONPWID}}(d_1 + t_{\text{MSM,NONPWID}} + u_1) \tag{S30}$$

$$\frac{dS_{\text{MSM,PWID,NONOAT}}}{dt} = S_{\text{MSM,NONPWID}} \cdot u_1 - \left(d_3 + t_{\text{MSM,PWID,NONOAT}} + u_2\right) \cdot S_{\text{MSM,PWID,NONOAT}} \tag{S31}$$

$$\frac{dS_{\text{MSM,PWID,OAT}}}{dt} = S_{\text{MSM,PWID,NONOAT}} u_2 - S_{\text{MSM,PWID,OAT}}(d_5 + t_{\text{MSM,PWID,OAT}}) \tag{S32}$$

$$\frac{dI_{\text{MSM,NONPWID}}}{dt} = S_{\text{MSM,NONPWID}} t_{\text{MSM,NONPWID}} - I_{\text{MSM,NONPWID}} \cdot (d_2 + u_3) \tag{S33}$$

$$\frac{dI_{\text{MSM,PWID,NONOAT}}}{dt} = I_{\text{MSM,NONPWID}} u_3 + S_{\text{MSM,PWID,NONOAT}} t_{\text{MSM,PWID,NONOAT}} - I_{\text{MSM,PWID,NONOAT}}(d_4 + u_4) \tag{S34}$$

$$\frac{dI_{\text{MSM,PWID,OAT}}}{dt} = S_{\text{MSM,PWID,OAT}} t_{\text{MSM,PWID,OAT}} + I_{\text{MSM,PWID,NONOAT}}(u_4 - d_6) \tag{S35}$$

$$\frac{dS_{\text{HM,NONPWID}}}{dt} = \delta P_2 - S_{\text{HM,NONPWID}}(d_1 + t_{\text{HM,NONPWID}} + u_1) \tag{S36}$$

$$\frac{dS_{\text{HM,PWID,NONOAT}}}{dt} = S_{\text{HM,NONPWID}} u_1 - S_{\text{HM,PWID,NONOAT}} \cdot \left(d_3 + t_{\text{HM,PWID,NONOAT}} + u_2\right) \tag{S37}$$

$$\frac{dS_{\text{HM,PWID,OAT}}}{dt} = S_{\text{HM,PWID,OAT}}(u_2 - d_5 - t_{\text{HM,PWID,OAT}}) \tag{S38}$$

$$\frac{dI_{\text{HM,NONPWID}}}{dt} = S_{\text{HM,NONPWID}} t_{\text{HM,NONPWID}} - I_{\text{HM,NONPWID}}(d_2 + u_3) \tag{S39}$$

$$\frac{dI_{\text{HM,PWID,NONOAT}}}{dt} = I_{\text{HM,NONPWID}} u_3 + S_{\text{HM,PWID,NONOAT}} t_{\text{HM,PWID,NONOAT}} - I_{\text{HM,PWID,NONOAT}}(d_4 + u_4) \tag{S40}$$

$$\frac{dI_{\text{HM,PWID,OAT}}}{dt} = S_{\text{HM,PWID,OAT}} t_{\text{HM,PWID,OAT}} + I_{\text{HM,PWID,NONOAT}} u_4 - I_{\text{HM,PWID,OAT}} d_6 \tag{S41}$$

$$\frac{dS_{\text{HW,NONPWID}}}{dt} = \delta P_3 - S_{\text{HW,NONPWID}}(d_1 + t_{\text{HW,NONPWID}} + u_1) \tag{S42}$$

$$\frac{dS_{\mathrm{HW,PWID,NONOAT}}}{dt} = S_{\mathrm{HW,NONPWID}} u_1 - S_{\mathrm{HW,PWID,NONOAT}} \cdot \left(d_3 + t_{\mathrm{HW,PWID,NONOAT}} + u_2\right) \quad \text{(S43)}$$

$$\frac{dS_{\mathrm{HW,PWID,OAT}}}{dt} = u_2 S_{\mathrm{HW,PWID,NONOAT}} - S_{\mathrm{HW,PWID,OAT}} (d_5 + t_{\mathrm{HW,PWID,OAT}}) \quad \text{(S44)}$$

$$\frac{dI_{\mathrm{HW,NONPWID}}}{dt} = S_{\mathrm{HW,NONPWID}} t_{\mathrm{HW,NONPWID}} - I_{\mathrm{HW,NONPWID}} (d_2 + u_3) \quad \text{(S45)}$$

$$\frac{dI_{\mathrm{HW,PWID,NONOAT}}}{dt} = I_{\mathrm{HW,NONPWID}} u_3 + S_{\mathrm{HW,PWID,NONOAT}} t_{\mathrm{HW,PWID,NONOAT}} - I_{\mathrm{HW,PWID,NONOAT}} (d_4 + u_4) \quad \text{(S46)}$$

$$\frac{dI_{\mathrm{HW,PWID,OAT}}}{dt} = S_{\mathrm{HW,PWID,OAT}} t_{\mathrm{HW,PWID,OAT}} + I_{\mathrm{HW,PWID,NONOAT}} u_4 - d_6 I_{\mathrm{HW,PWID,OAT}} \quad \text{(S47)}$$

To calculate the mortality rates among HIV+ and HIV- PWID, who are not on OAT we used the following specification: $d_3 = d_5 * \mathbf{mrr_{oat}}$ and $d_4 = d_6 * \mathbf{mrr_{oat}}$ due to a lack of actual mortality data among PWID.

2.5 Model Calibration

The data on the total population size in each region is taken from the Census published by the State Statistics Services in Ukraine, while the estimates for the size of at risk population, i.e. PWID and MSM, are taken from analytical reports published by AIDS Alliance for Public Health.[14,15] The estimates of at-risk populations, however, have a wide confidence intervals due to a high degree of uncertainty. In order to calibrate the modeling parameters that would account for uncertainty in the size of at-risk-populations, we develop a novel "Minimum Step Deviation" algorithm.

Steps of MSD Algorithm:

1. Application of the method of the least squares (OLS) to calibrate parameters using total numbers of people living with HIV. The new set of calibrated parameters set Θ^* is saved for step 6.
2. Application of OLS to calibrate parameters using the number of HIV+ MSM in each region in order to calculate calibrated parameter set χ^*.
3. Application of OLS to calibrate parameter using number of PWID living with HIV in order to calculate calibrated parameter set κ^*.
4. Estimation of the model using parameter set χ^* to get number of HIV+ MSM, as well as 90% Confidence interval . The resulting confidence bounds are compared to 90% CI based on the empirical distribution of HIV+ MSM and used to estimate the derive the final CI of HIV+ MSM, denoted as CI_{MSMHIV}.
5. Estimation of the model using parameter set κ^*. Calculation of the number of PWID who are HIV+ , as well as 90% CI (denoted as $\mathrm{CI}_{PWIDHIV}$) based on the model's output as well as the data.
6. Estimation of the model using parameters set Θ^*(from step 1), The algorithm progresses to the next step if the number of HIV+ MSM from model is within CI_{MSMHIV}. If the condition is not satisfied, a minimum step $w_1{}^*$ is computed from $\Omega 1^* = (1 - w_1{}^*)\Theta^* + w_1{}^* \chi^*$, such that the number of HIV+ MSM is within confidence bounds CI_{MSMHIV}.
7. Estimation of the model using parameters set $\Omega 1^*$. The algorithm terminates with $\Omega 1^*$ being the final calibrated parameter set if the estimated number of HIV+ PWID from the model is within confidence interval $\mathrm{CI}_{PWIDHIV}$. If the condition is not satisfied the minimum step $w_2{}^*$is calculated iteratively $\Omega 2^* = (1 - w_2{}^*)\Omega 1^* + w_2{}^* \kappa^*$ until the number of HIV+ PWID is within the confidence bounds $\mathrm{CI}_{PWIDHIV}$ and $\Omega 2^*$ is the final calibrated parameters set.

In addition, we conservatively assumed that the frequency of injection per day, as well as probability of sharing paraphernalia, was higher among non-OAT relative to PWID on OAT. We also assumed that the probability of HIV transmission following unprotected sex behavior among MSM[7] is larger than the probability of HIV Transmission given unprotected sex behavior among non-MSM.

Calibration mathematical expression:

In order to make model easy to read, we denote:

$\tilde{Y}_{HIV-}(t,\Theta)$: Value $\tilde{Y}_{HIV-}$ at time $t, under$ Θ parameters set (S48)

$$\tilde{Y}_{HIV-}(t,\Theta) = S_{\mathrm{MSM,NONPWID}}(t,\Theta) + S_{\mathrm{MSM,PWID,NONOAT}}(t,\Theta) + S_{\mathrm{MSM,PWID,OAT}}(t,\Theta) + S_{\mathrm{HM,NONPWID}}(t,\Theta) + S_{\mathrm{HM,PWID,NONOAT}}(t,\Theta) + S_{\mathrm{HM,PWID,OAT}}(t,\Theta) + S_{\mathrm{HW,NONPWID}}(t,\Theta) + S_{\mathrm{HW,PWID,NONOAT}}(t,\Theta) + S_{\mathrm{HW,PWID,OAT}}(t,\Theta) \quad \text{(S49)}$$

$$\tilde{Y}_{HIV+}(t,\Theta) = I_{\mathrm{MSM,NONPWID}}(t,\Theta) + I_{\mathrm{MSM,PWID,NONOAT}}(t,\Theta) + I_{\mathrm{MSM,PWID,OAT}}(t,\Theta) + I_{\mathrm{HM,NONPWID}}(t,\Theta) + I_{\mathrm{HM,PWID,NONOAT}}(t,\Theta) + I_{\mathrm{HM,PWID,OAT}}(t,\Theta) + I_{\mathrm{HW,NONPWID}}(t,\Theta) + I_{\mathrm{HW,PWID,NONOAT}}(t,\Theta) + I_{\mathrm{HW,PWID,OAT}}(t,\Theta) \quad \text{(S50)}$$

$$\tilde{Y}_{MSMHIV+}(t,\chi) = I_{\mathrm{MSM,NONPWID}}(t,\chi) + I_{\mathrm{MSM,PWID,NONOAT}}(t,\chi) + I_{\mathrm{MSM,PWID,OAT}}(t,\chi) \quad \text{(S51)}$$

$$\tilde{Y}_{PWIDHIV+}(t,\kappa) = I_{\mathrm{MSM,PWID,OAT}}(t,\kappa) + I_{\mathrm{MSM,PWID,NONOAT}}(t,\kappa) + I_{\mathrm{HM,PWID,OAT}}(t,\kappa) + I_{\mathrm{HM,PWID,NONOAT}}(t,\kappa) + I_{\mathrm{HW,PWID,OAT}}(t,\kappa) + I_{\mathrm{HW,PWID,NONOAT}}(t,\kappa) \quad \text{(S52)}$$

$$\tilde{Y}_{Total}(t,\chi^*) = \tilde{Y}_{HIV+}(t,\chi^*) + \tilde{Y}_{HIV-}(t,\chi^*) \quad \text{(S53)}$$

$$\tilde{Y}_{Total}(t,\kappa^*) = \tilde{Y}_{HIV+}(t,\kappa^*) + \tilde{Y}_{HIV-}(t,\kappa^*) \quad \text{(S54)}$$

$$\tilde{\theta}_{MSMHIV+}(t,\chi^*) = \frac{\tilde{Y}_{MSMHIV+}(t,\chi^*)}{\tilde{Y}_{Total}(t,\chi^*)} \quad \text{(S55)}$$

$$\theta_{MSMHIV+}(t) = \frac{Y_{MSMHIV+}(t)}{Y_{Total}(t)} \quad \text{(S56)}$$

$$\tilde{\theta}_{PWIDHIV+}(t,\kappa^*) = \frac{\tilde{Y}_{PWIDHIV+}(t,\kappa^*)}{\tilde{Y}_{Total}(t,\kappa^*)} \quad \text{(S57)}$$

$$\theta_{PWIDHIV+}(t) = \frac{Y_{PWIDHIV+}(t)}{Y_{Total}(t)} \quad \text{(S58)}$$

$Y_{HIV+}(t)$ is size of total population living with HIV at time t based on empirical data.

$Y_{MSMHIV+}(t)$ is size of MSM population living with HIV at time t based on empirical data.

$Y_{PWIDHIV+}(t)$ is size of PWID population living with HIV at time t based on empirical data.

$Y_{Total}(t)$ is size of the population at time t based on empirical data.

$\widetilde{\imath du\imath n}(t)$ is the HIV incidence among PWID at time t from the model.

$\widetilde{\imath n(t)}$ is the HIV incidence in the total population at time t from the model.

$iduin(t)$ is the HIV incidence among PWID at time t.

$in(t)$ is the HIV incidence in the population at time t.

$$\min f(\Theta) \quad \text{(S59)}$$

Such that:

$$f(\Theta) = \sum_t (Y_{HIV+}(t) - \tilde{Y}_{HIV+}(t, \Theta))^2; \quad \text{(S60)}$$

$$\beta_2 \leq \beta_1 \; ; \; f_2 \leq f_1 \; ; \quad \text{(S61)}$$

$$\sigma_M \leq \sigma_F \leq \sigma_{MSM} \; ; \{d_1, d_2, d_3, d_4, d_5, d_6\} \in [0,1] \; ; \; \{\mathrm{f}, f_1, f_2\} \in [0,1]; \quad \text{(S62)}$$

$$\{\mathrm{f}, f_1, f_2\} \in [0,1] \; ; \{\alpha, \beta_1, \beta_2\} \in [0, +\infty] \; ; \{u_1, u_2, u_3, u_4\} \in [-1,1] \; ; \{\sigma_{MSM}, \sigma_M, \sigma_F, \sigma_I\} \in [0,1]; \quad \text{(S63)}$$

$$d_1 \leq d_2 \; ; \; d_3 \leq d_4 \; ; \; d_5 \leq d_6 \; ; \; d_1 \leq d_3 \; ; \; d_2 \leq d_4 \; ; \; d_5 \leq d_3 \; ; \; d_6 \leq d_4 \; ; \quad \text{(S64)}$$

$$\Theta = \{d_1, d_2, d_3, d_4, d_5, d_6, u_1, u_2, u_3, u_4, \alpha, \mathrm{f}, \beta_1, \beta_2, f_1, f_2, \sigma_{MSM}, \sigma_M, \sigma_F, \sigma_I\}; \quad \text{(S65)}$$

$$\min g(\chi) \quad \text{(S66)}$$

Such that

$$g(\chi) = \sum_t (Y_{MSMHIV+}(t) - \tilde{Y}_{MSMHIV+}(t, \chi))^2 \quad \text{(S67)}$$

$$\beta_2 \leq \beta_1 \; ; \; f_2 \leq f_1 \; ; \quad \text{(S68)}$$

$$\sigma_M \leq \sigma_F \leq \sigma_{MSM} \; ; \{d_1, d_2, d_3, d_4, d_5, d_6\} \in [0,1] \; ; \; \{\mathrm{f}, f_1, f_2\} \in [0,1]; \quad \text{(S69)}$$

$$\{\mathrm{f}, f_1, f_2\} \in [0,1] \; ; \{\alpha, \beta_1, \beta_2\} \in [0, +\infty] \; ; \{u_1, u_2, u_3, u_4\} \in [-1,1] \; ; \{\sigma_{MSM}, \sigma_M, \sigma_F, \sigma_I\} \in [0,1]; \quad \text{(S70)}$$

$$d_1 \leq d_2 \; ; \; d_3 \leq d_4 \; ; \; d_5 \leq d_6 \; ; \; d_1 \leq d_3 \; ; \; d_2 \leq d_4 \; ; \; d_5 \leq d_3 \; ; \; d_6 \leq d_4 \; ; \quad \text{(S71)}$$

$$\chi = \{d_1, d_2, d_3, d_4, d_5, d_6, u_1, u_2, u_3, u_4, \alpha, \mathrm{f}, \beta_1, \beta_2, f_1, f_2, \sigma_{MSM}, \sigma_M, \sigma_F, \sigma_I\}; \quad \text{(S72)}$$

$$\min h(\kappa) \quad \text{(S73)}$$

Such that

$$h(\kappa) = \sum_{t}(Y_{PWIDHIV+}(t) - \tilde{Y}_{PWIDHIV+}(t,\kappa))^2 \quad \text{(S74)}$$

$$\beta_2 \leq \beta_1 \; ; \; f_2 \leq f_1 \; ; \quad \text{(S75)}$$

$$\sigma_M \leq \sigma_F \leq \sigma_{MSM} \; ; \{d_1, d_2, d_3, d_4, d_5, d_6\} \in [0,1] \; ; \; \{\mathrm{f}, f_1, f_2\} \in [0,1];$$

$$\{\mathrm{f}, f_1, f_2\} \in [0,1] \; ; \{\alpha, \beta_1, \beta_2\} \in [0, +\infty] \; ; \{u_1, u_2, u_3, u_4\} \in [-1,1] \; ; \{\sigma_{MSM}, \sigma_M, \sigma_F, \sigma_I\} \in [0,1]; \quad \text{(S77)}$$

(S78)

$$d_1 \leq d_2 \; ; \; d_3 \leq d_4 \; ; \; d_5 \leq d_6 \; ; \; d_1 \leq d_3 \; ; \; d_2 \leq d_4 \; ; \; d_5 \leq d_3 \; ; \; d_6 \leq d_4 \; ;$$

$$\kappa = \{d_1, d_2, d_3, d_4, d_5, d_6, u_1, u_2, u_3, u_4, \alpha, \mathrm{f}, \beta_1, \beta_2, f_1, f_2, \sigma_{MSM}, \sigma_M, \sigma_F, \sigma_I\}; \quad \text{(S79)}$$

$$\min w_1 \quad \text{(S80)}$$

Such that:

Lower(t, χ^*)=

$$\min\begin{pmatrix} \tilde{Y}_{Total}(t,\chi^*) \cdot \left(\tilde{\theta}_{MSMHIV+}(t,\chi^*) - 1.96\sqrt{\frac{\tilde{\theta}_{MSMHIV+}(t,\chi^*)(1-\tilde{\theta}_{MSMHIV+}(t,\chi^*))}{\tilde{Y}_{Total}(t,\chi^*)}}\right) \; , \\ Y_{Total}(t) \cdot \left(\theta_{MSMHIV+}(t) - 1.96\sqrt{\frac{\theta_{MSMHIV+}(t)(1-\theta_{MSMHIV+}(t))}{Y_{\_Total}(t)}}\right) \end{pmatrix}; \quad \text{(S81)}$$

Upper(t, χ^*)=

$$\max\begin{pmatrix} \tilde{Y}_{Total}(t,\chi^*) \cdot \left(\tilde{\theta}_{\_MSMHIV+}(t,\chi^*) + 1.96\sqrt{\frac{\tilde{\theta}_{\_MSMHIV+}(t,\chi^*)(1-\tilde{\theta}_{\_MSMHIV+}(t,\chi^*))}{\tilde{Y}_{\_Total}(t,\chi^*)}}\right) \; , \\ Y_{Total}(t) \cdot \left(\theta_{MSMHIV+}(t) + 1.96\sqrt{\frac{\theta_{MSMHIV+}(t)(1-\theta_{MSMHIV+}(t))}{Y_{\_Total}(t)}}\right) \end{pmatrix}; \quad \text{(S82)}$$

(S83)

$$\Omega 1 = (1 - w_1)\Theta^* + w_1\chi^* \; ; \; \mathrm{Lower}(t,\chi^*) \leq \tilde{Y}_{\_MSMHIV+}(t, \Omega 1) \leq \mathrm{Upper}(t,\chi^*) \; ;$$

$$\beta_2 \leq \beta_1 \; ; \; f_2 \leq f_1 \; ; \; 0 \leq w_1 \leq 1; \quad \text{(S84)}$$

$$\sigma_M \leq \sigma_F \leq \sigma_{MSM} \; ; \{d_1, d_2, d_3, d_4, d_5, d_6\} \in [0,1] \; ; \; \{\mathrm{f}, f_1, f_2\} \in [0,1]; \quad \text{(S85)}$$

(S86)

$$\{\mathrm{f}, f_1, f_2\} \in [0,1] \; ; \{\alpha, \beta_1, \beta_2\} \in [0, +\infty] \; ; \{u_1, u_2, u_3, u_4\} \in [-1,1] \; ; \{\sigma_{MSM}, \sigma_M, \sigma_F, \sigma_I\} \in [0,1];$$

$$d_1 \leq d_2 \; ; \; d_3 \leq d_4 \; ; \; d_5 \leq d_6 \; ; \; d_1 \leq d_3 \; ; \; d_2 \leq d_4 \; ; \; d_5 \leq d_3 \; ; \; d_6 \leq d_4 \; ; \quad \text{(S87)}$$

$$\min w_2 \quad \text{(S88)}$$

Such that:

$$\text{Lower}(t,\kappa^*) = \min\left(\begin{array}{c} \tilde{Y}_{Total}(t,\kappa^*) \cdot \left(\tilde{\theta}_{PWIDHIV+}(t,\kappa^*) - 1.96\sqrt{\frac{\tilde{\theta}_{PWID,HIV+}(t,\kappa^*)\left(1-\tilde{\theta}_{PWID,HIV+}(t,\kappa^*)\right)}{\tilde{Y}_{Total}(t,\kappa^*)}} \right), \\ Y_{Total}(t) \cdot \left(\theta_{PWIDHIV+}(t) - 1.96\sqrt{\frac{\theta_{PWID,HIV+}(t)\left(1-\theta_{PWID,HIV+}(t)\right)}{Y_{Total}(t)}} \right) \end{array} \right) \quad \text{(S89)}$$

$$\text{Upper}(t,\kappa^*) = \max\left(\begin{array}{c} \tilde{Y}_{Total}(t,\kappa^*) \cdot \left(\tilde{\theta}_{PWID,HIV+}(t,\kappa^*) + 1.96\sqrt{\frac{\tilde{\theta}_{PWID,HIV+}(t,\kappa^*)\left(1-\tilde{\theta}_{PWIDHIV+,}(t,\kappa^*)\right)}{\tilde{Y}_{Total}(t,\kappa^*)}} \right), \\ Y_{Total}(t) \cdot \left(\theta_{PWID,HIV+}(t) + 1.96\sqrt{\frac{\theta_{PWID,HIV+}(t)\left(1-\theta_{PWID,HIV+}(t)\right)}{Y_{Total}(t)}} \right) \end{array} \right); \quad \text{(S90)}$$

$$\Omega 2 = (1-w_2)\Omega 1^* + w_2\kappa^* \ ; \text{Lower}(t,\kappa^*) \le \tilde{Y}_{PWIDHIV+}(t,\Omega 2) \le \text{Upper}(t,\kappa^*); \quad \text{(S91)}$$

$$\beta_2 \le \beta_1 \ ; \ f_2 \le f_1 \ ; \ 0 \le w_2 \le 1; \quad \text{(S92)}$$

$$\sigma_M \le \sigma_F \le \sigma_{MSM} \ ; \{d_1,d_2,d_3,d_4,d_5,d_6\} \in [0,1] \ ; \ \{\text{f}, f_1, f_2\} \in [0,1]; \quad \text{(S93)}$$

$$\{\text{f}, f_1, f_2\} \in [0,1] \ ; \{\alpha, \beta_1, \beta_2\} \in [0,+\infty] \ ; \{u_1,u_2,u_3,u_4\} \in [-1,1] \ ; \{\sigma_{MSM}, \sigma_M, \sigma_F, \sigma_I\} \in [0,1]; \quad \text{(S94)}$$

$$d_1 \le d_2 \ ; \ d_3 \le d_4 \ ; \ d_5 \le d_6 \ ; \ d_1 \le d_3 \ ; \ d_2 \le d_4 \ ; \ d_5 \le d_3 \ ; \ d_6 \le d_4 \ ; \quad \text{(S95)}$$

$$\min\left(\frac{|\widetilde{iduin\,(t},\Omega 3) - iduin(t)|}{iduin(t)} + \frac{|\widetilde{in(t,\Omega}3) - in(t)|}{in(t)}\right) \quad \text{(S96)}$$

Such that:

$$\Omega 2^* - \delta_2 \le \Omega 3 \le \Omega 2^* + \delta_1 \quad \text{(S97)}$$

$$\beta_2 \le \beta_1 \ ; \ f_2 \le f_1 \ ; \quad \text{(S98)}$$

$$\sigma_F \le \sigma_{MSM} \ ; \{d_1,d_2,d_3,d_4,d_5,d_6\} \in [0,1] \ ; \ \{\text{f}, f_1, f_2\} \in [0,1]; \quad \text{(S99)}$$

$$\{\text{f}, f_1, f_2\} \in [0,1] \ ; \{\alpha, \beta_1, \beta_2\} \in [0,+\infty] \ ; \{u_1,u_2,u_3,u_4\} \in [-1,1] \ ; \{\sigma_{MSM}, \sigma_M, \sigma_F, \sigma_I\} \in [0,1]; \quad \text{(S100)}$$

$$d_1 \le d_2 \ ; \ d_3 \le d_4 \ ; \ d_5 \le d_6 \ ; \ d_1 \le d_3 \ ; \ d_2 \le d_4 \ ; \ d_5 \le d_3 \ ; \ d_6 \le d_4 \ ; \quad \text{(S101)}$$

2.5 Model Validation

The Model is validated against HIV prevalence and HIV incidence 2015-2016. The final validation results are contained in the table S5. The HIV prevalence estimates among PWID, as well as estimates on the population size of PWID and MSM are derived from bi-annual integrated bio-behavioral survey (IBBS), data collected and published by AIDS Alliance in Ukraine[14-16]. Due to high variability within city estimates from 2011-2015, stemming from RDS-based small samples, we developed an extension of an EM Algorithm to calculate the weighted average HIV prevalence in the time interval, as the data published in not sufficient in scope and duration to analyze the time-series properties of the statistics.[17] Figures S2-S25 Panel (A) contain EM estimates as well as the depiction of the original data.

The HIV incidence by region is based on the number of reported new infections as published by Ministry of Health.[8] The number of new diagnosed infections is weighted by the proportion of population aware of their HIV infection as published by UNAIDS. We calculated the rate of incidence per year using the number of HIV negative population among PWID and non-PWID members in the denominator. In addition, we analyzed our estimate of incidence of HIV among PWID to the HIV incidence rate that was provided to us from the 2017 IBBS, which for the first time, included incidence data using recent HIV infection algorithms. Overall we found that the estimates from the two sources to be very close to one another, and in our study is based on data published by the Ukranian Ministry of Health (Center for Public Health).

Table S5: Model Validation

	HIV Prevalence		HIV Incidence	
Regions	Data	Model	Data	Model
Dnipro	32.54 (28.4, 36.6)	32.28 (31.44-33.11)	4.94 (4.7, 5.2)	5.69 (5.10, 7.49)
Odesa	31.04 (26.8, 35.3)	30.10 (28.60-32.24)	2.16 (2.0, 2.3)	3.40 (2.09, 6.96)
Kyiv (city)	21.39 (17.4, 25.4)	21.32 (19.95-22.4)	2.13 (2.0, 2.3)	2.18 (1.81, 2.35)
Kharkiv	10.47 (6.2, 14.7)	10.44 (9.31-11.33)	1.55 (1.3, 1.8)	1.37 (0.80, 1.58)
Sumy	7.2 (3.1, 11.3)	7.15 (6.35-7.73)	0.82 (0.7, 1.0)	0.81 (0.45, 0.94)
Zaporizhia	7.58 (3.3, 11.8)	7.74 (6.61-8.75)	2.82 (2.5, 3.2)	2.23 (1.55, 2.62)
Mykolaiv	34.71 (30.5, 38.9)	32.66 (31.32-34.25)	2.45 (2.1, 2.8)	4.53 (2.35, 6.38)
Cherkasy	21.41 (17.1, 25.7)	20.04 (17.69-22.28)	2.83 (2.5, 3.2)	2.63 (1.24, 3.10)
Lviv	21.83 (17.8, 25.9)	20.64 (18.68-22.92)	2.74 (2.4, 3.1)	2.74 (1.73, 3.56)
Kherson	24.73 (20.5, 29.0)	24.48 (22.28-26.89)	2.76 (2.4, 3.1)	2.83 (1.91, 4.73)

Kirovohrad	11.03 (7.5, 14.6)	11.60 (10.42-12.47)	2.24 (1.9, 2.6)	1.89 (1.51, 2.11)
Khmelnytskyi	27.38 (23.3, 31.5)	23.00 (20.20-25.18)	0.57 (0.4, 0.8)	0.82 (0.57, 1.19)
Poltava	23.38 (16.6, 30.2)	23.28 (21.57-24.57)	2.48 (2.1, 2.9)	4.11 (3.01, 4.55)
Kyiv	23.05 (18.3, 27.8)	23.98 (20.84- 26.74)	4.85 (4.3, 5.4)	7.8 (4.48, 9.34)
Chernihiv	30.13 (25.4, 34.9)	30.59 (28.74-33.17)	5.11 (4.5, 5.7)	4.8 (3.3, 5.2)
Volyn	20.24 (15.7, 24.7)	17.21 (15.83-19.06)	1.15 (0.8, 1.5)	1.52 (0.58, 4.46)
Vinnytsia	11.31 (7.4, 15.2)	10.32 (9.35-10.88)	1.01 (0.8, 1.3)	1.10 (0.96, 1.20)
Rivne	14.5 (11.0, 18.0)	12.67 (10.90-14.29)	1.60 (1.2, 2)	1.66 (0.63, 2.48)
Ternopil	11.93 (8.5, 15.3)	9.71 (7.80-11.68)	0.56 (0.3, 0.8)	0.67 (0.54, 0.80)
Ivano-Frankivsk	17.42 (13.5, 21.4)	14.36 (12.29-16.13)	1.71 (1.3, 2.2)	1.50 (0.46, 1.78)
Chernivtsi	4.58 (1.2, 7.9)	4.05 (2.66-5.07)	0.62 (0.4, 0.9)	0.58 (0.25, 1.0)
Zhytomyr	18.96 (14.9, 23.1)	19.44 (17.45-20.85)	6.95 (6.0, 7.9)	5.23 (3.17, 5.92)
Zakarpattia	1.59 (0.004, 3.3)	1.39 (1.19-1.58)	0.44 (0.2, 0.7)	0.34 (0.25, 0.42)

Source: Calculation based on data from IBBS & Ukrainian Center for Socially Dangerous Disease Control

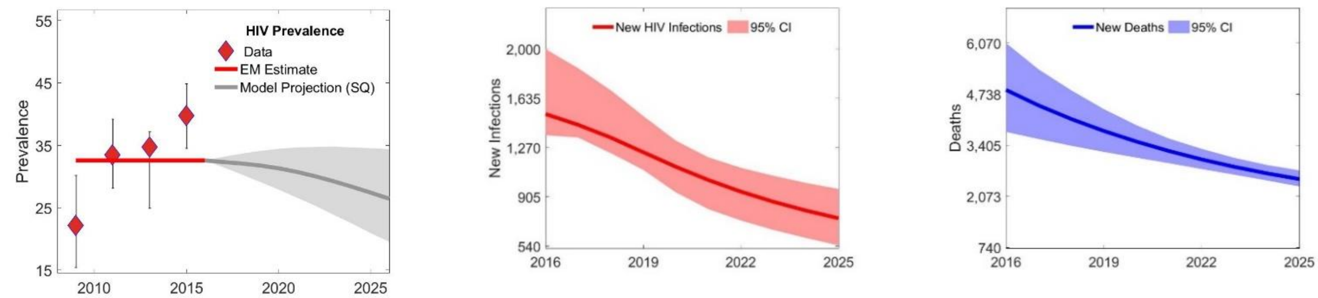
Regional Plots Description

For each of the regions (Panel A below), we provide the following depictions for trajectories of HIV prevalence, new HIV infections and deaths. For HIV prevalence, we depict in red diamonds published point estimates from the Alliance for Public Health published reports from 2011 to 2016 (with error bars capturing the published 95% confidence interval), a straight red line is estimated prevalence based on application of expectation maximization algorithm to the available data; followed by the projected prevalence in our status quo model. The Status Quo (SQ) scenario is based on assumption of no additional OAT scale-up. For new infections and death, we provide the trajectory over time with 95% confidence limits. For Panel B, we first provide the estimation for PWID population size, where the red dots represent the means of the numbers of PWID in the region, with the red lines representing the 95% confidence intervals for the population estimates for the region. Thereafter, the number of PWID from the model projection is presented. In the next two figures is the number of projected HIV infections and deaths averted over time at various levels of OAT coverage. Panel C is the sensitivity analysis for the region for deaths and new infections averted, which is varied by population size.

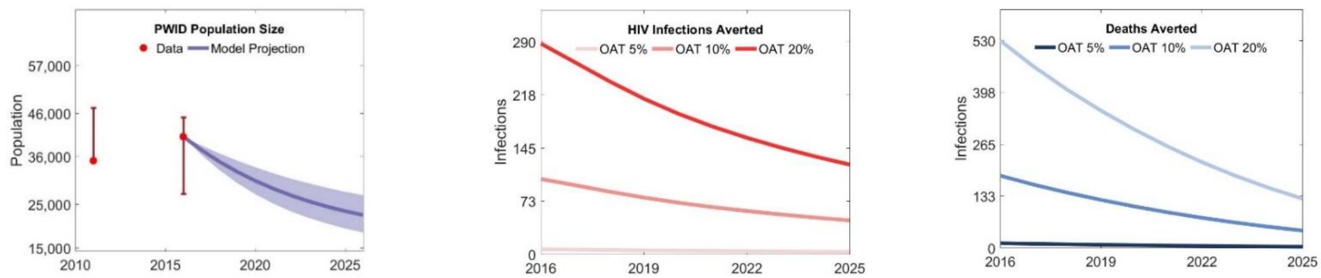
Figure S2. Region: Dnipro (1)

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



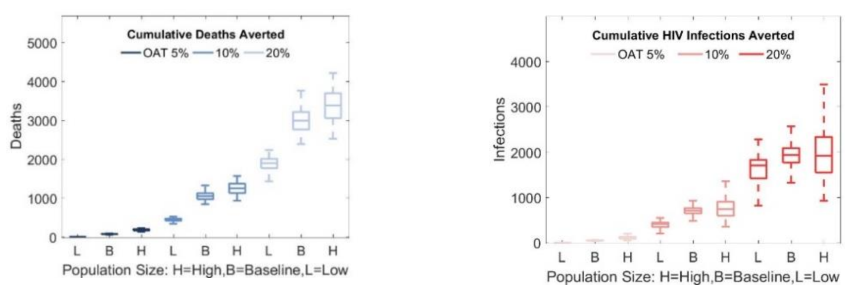
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

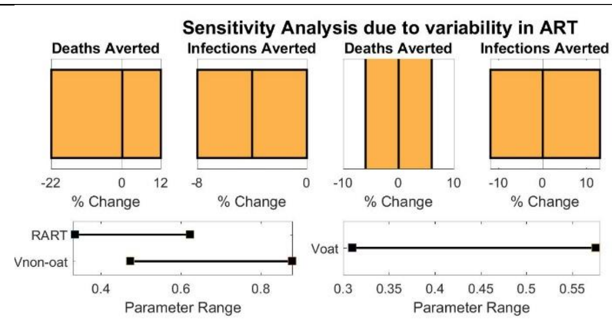
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



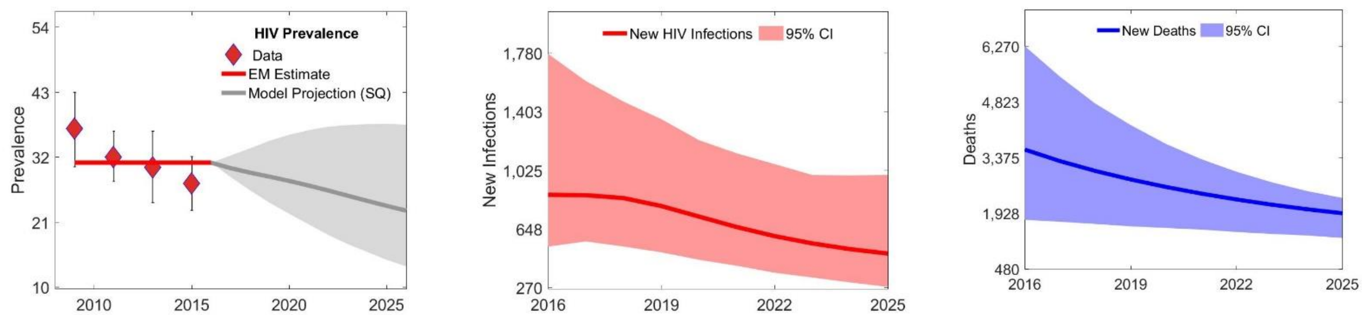
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

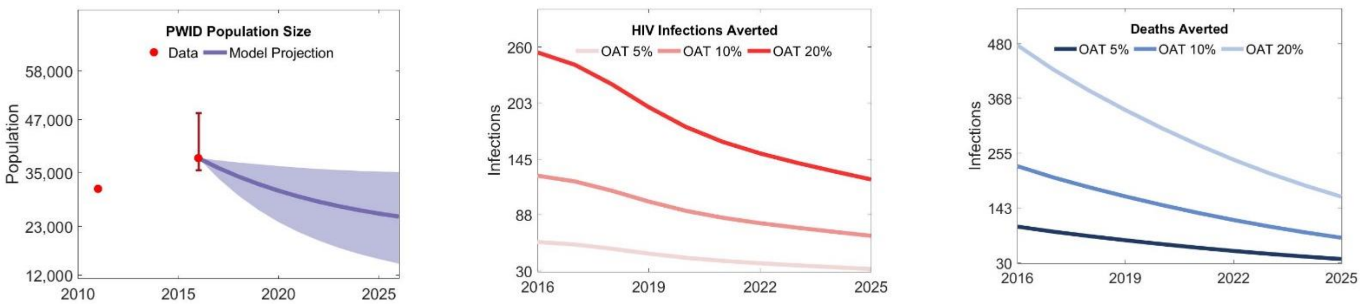
Figure S3: Region: **Odesa**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



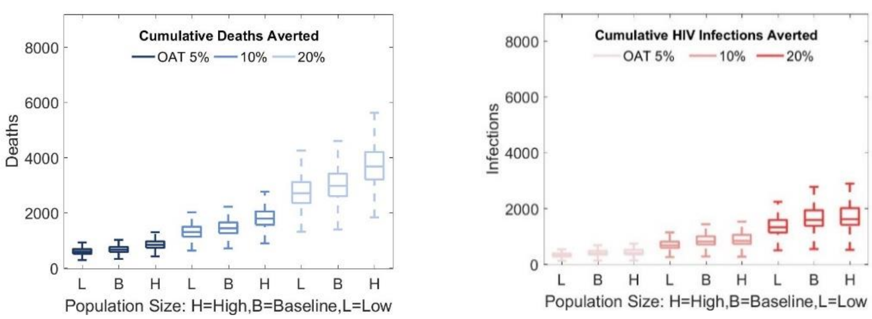
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

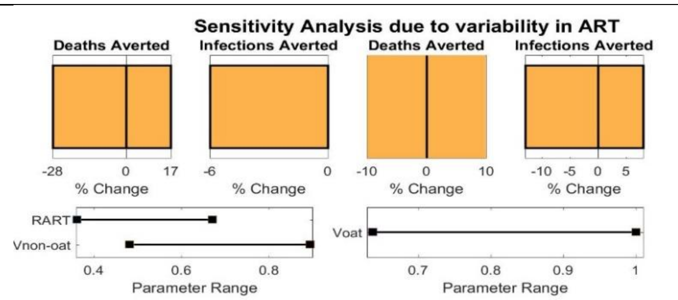
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



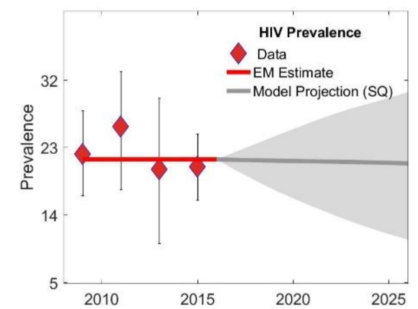
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

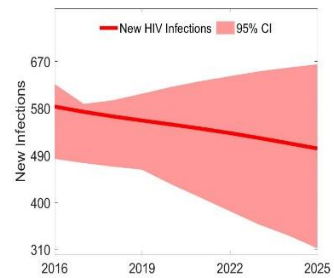
ART parameters are varied by +/- 30% of their observed base-value in each region

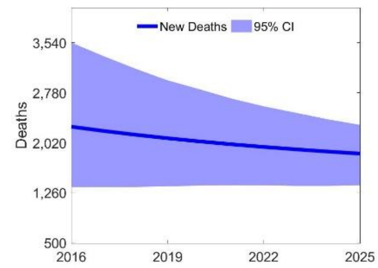
Figure S4. Region: **Kyiv City**

Data and Model Projections Under Different OAT Scale-up Scenarios

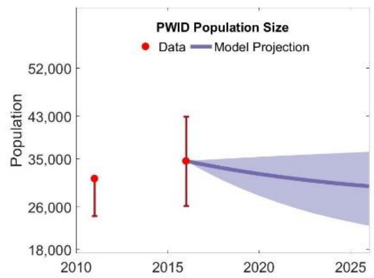
(A)

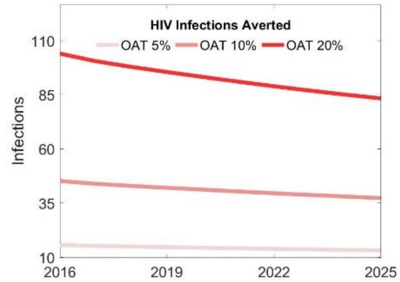


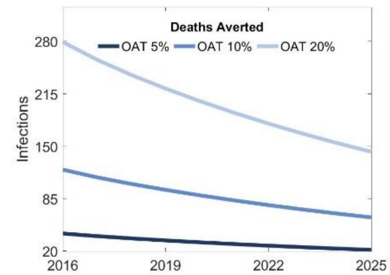




(B)



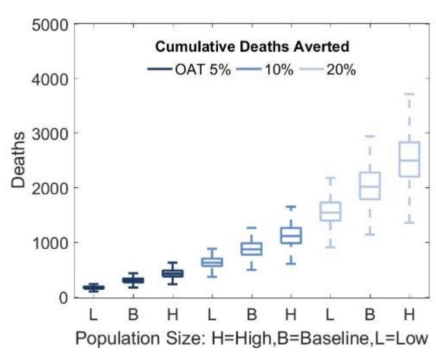


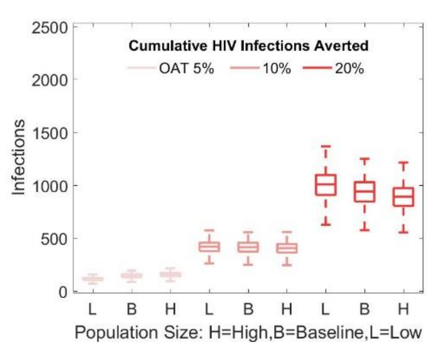


Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

(C)

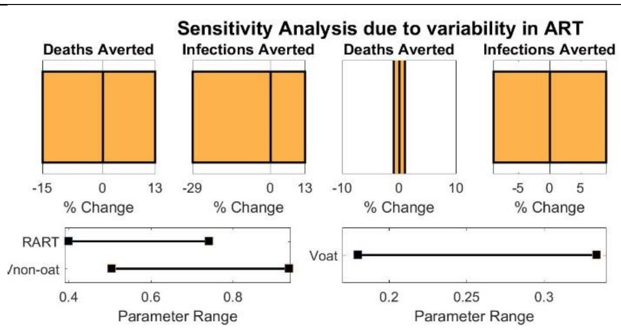




Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



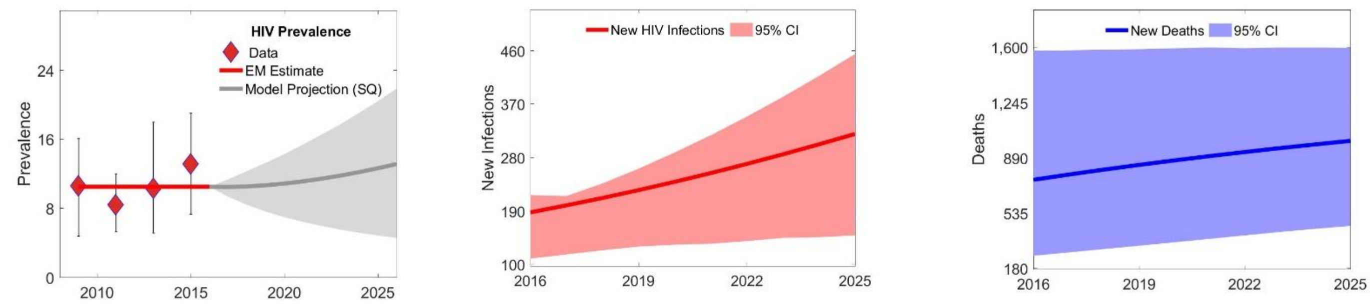
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

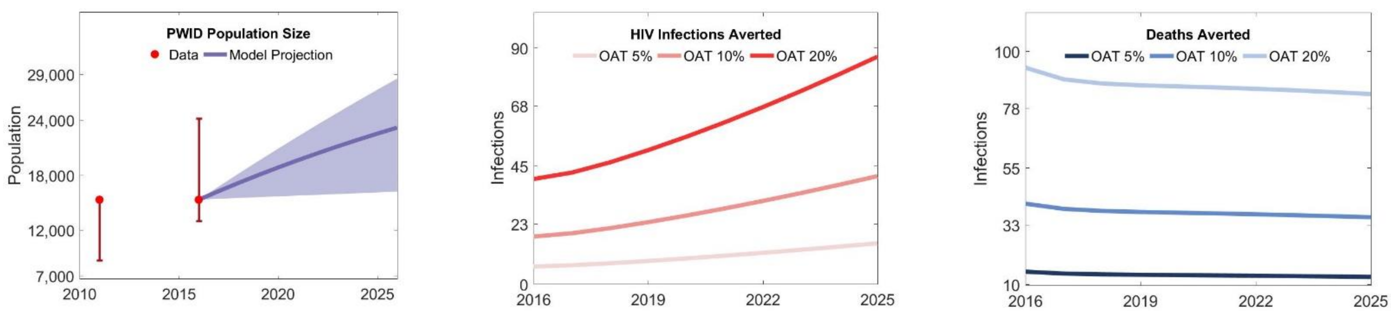
Figure S5. Region: **Kharkiv**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



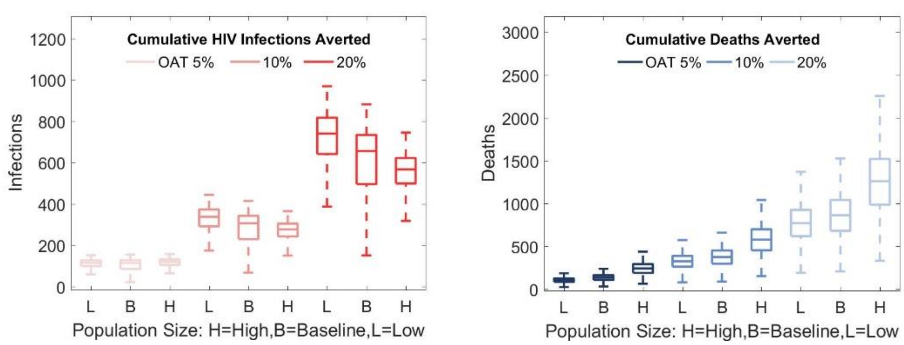
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

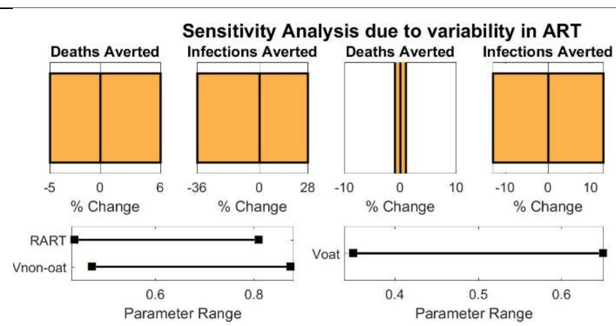
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



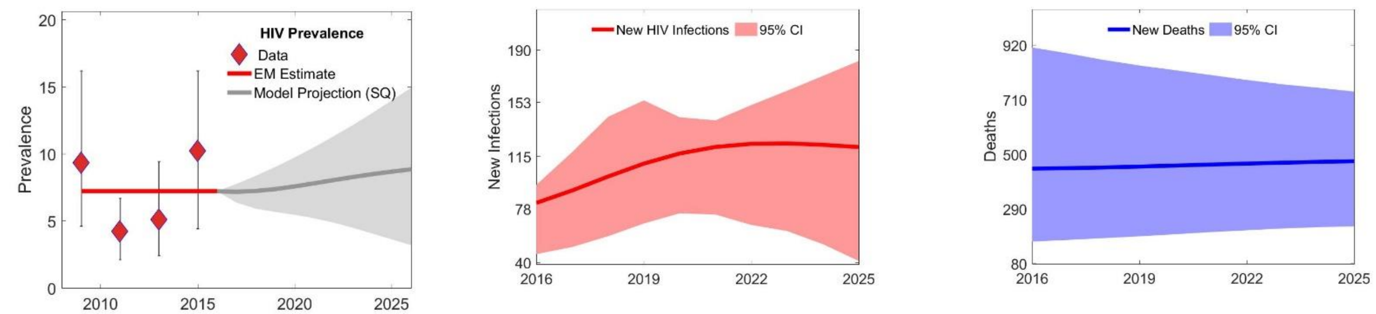
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

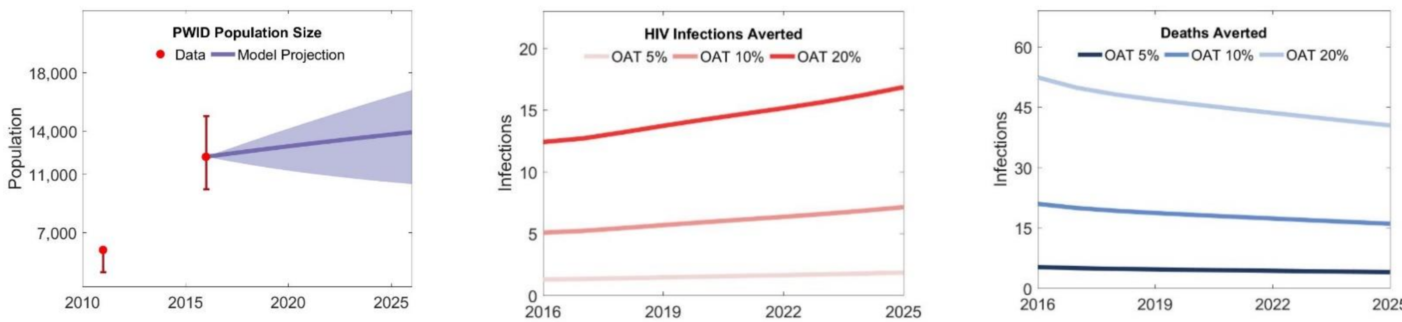
Figure S6. Region: **Sumy**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



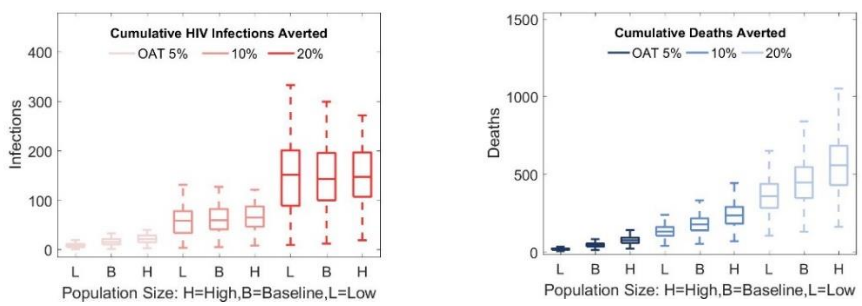
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

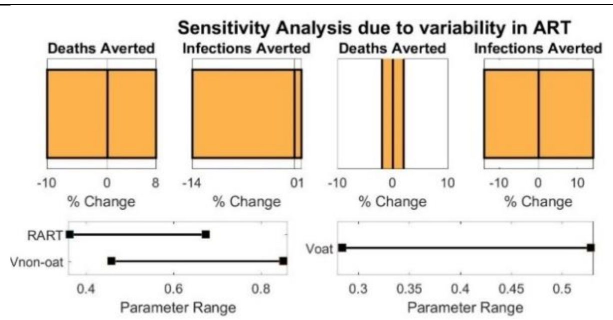
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



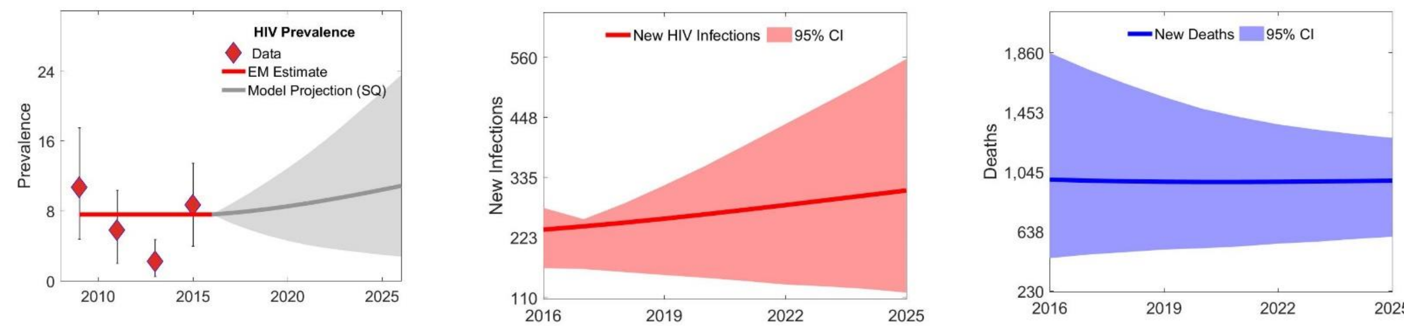
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

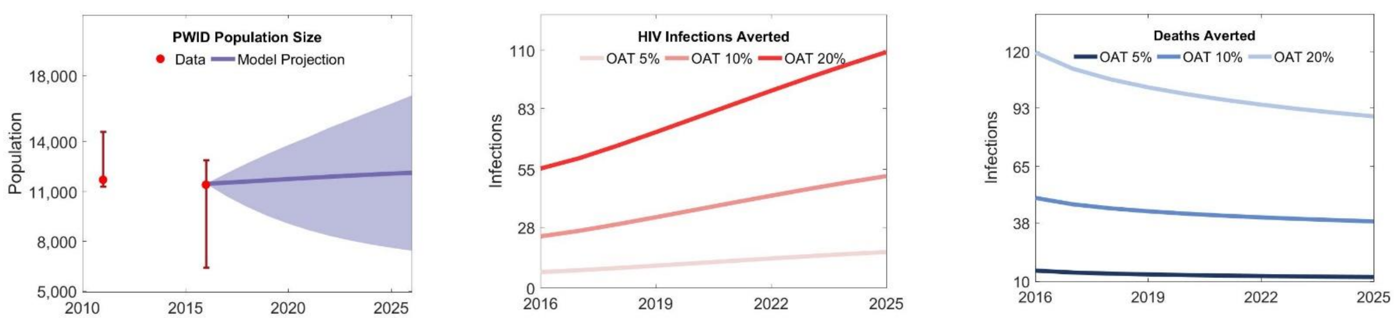
Figure S7. Region: **Zaporizhia**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



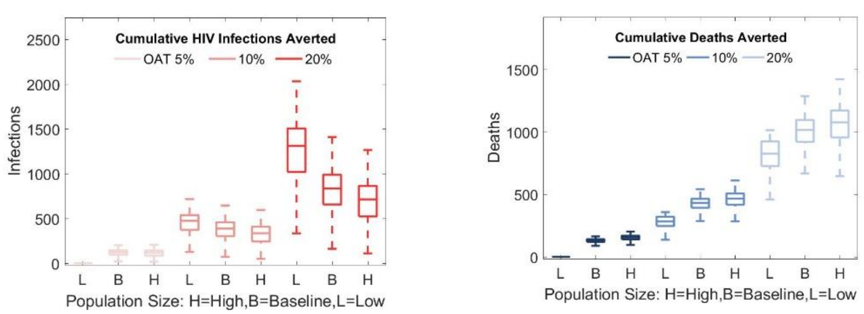
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

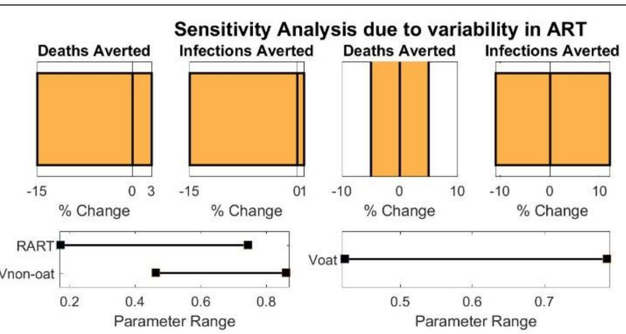
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25[th] and 75[th] quartiles, while whiskers – outliers

(D)



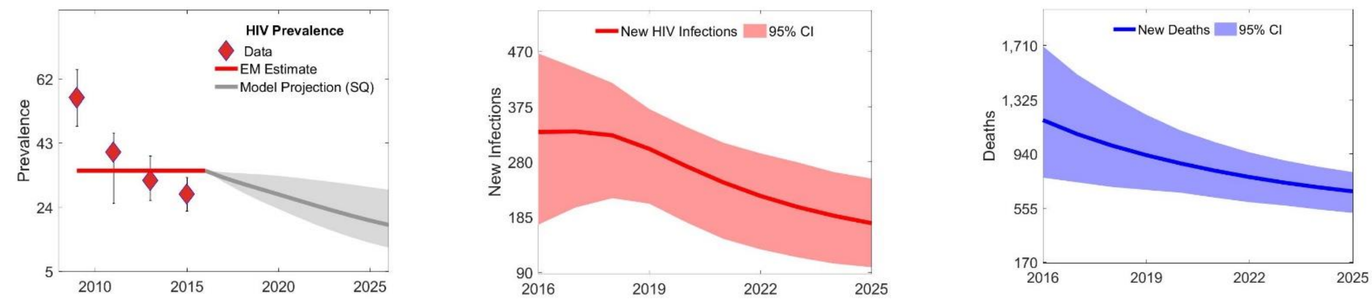
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

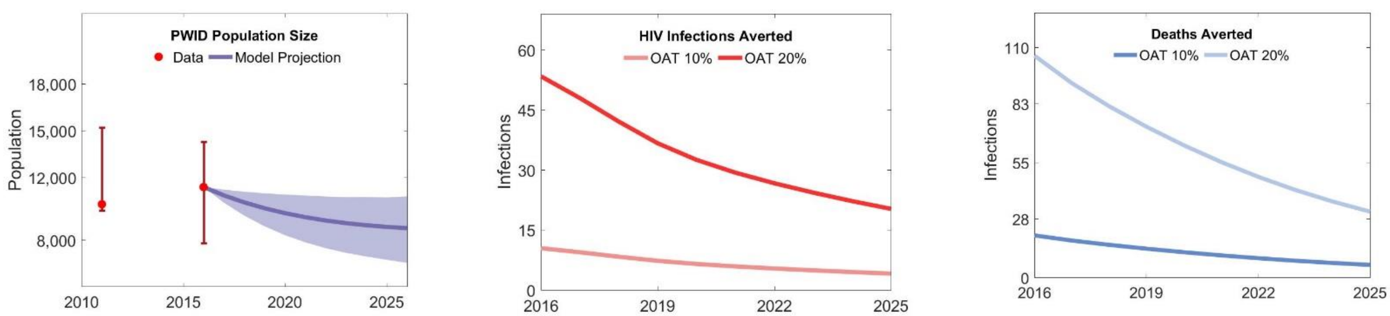
Figure S8. Region: **Mykolaiv**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



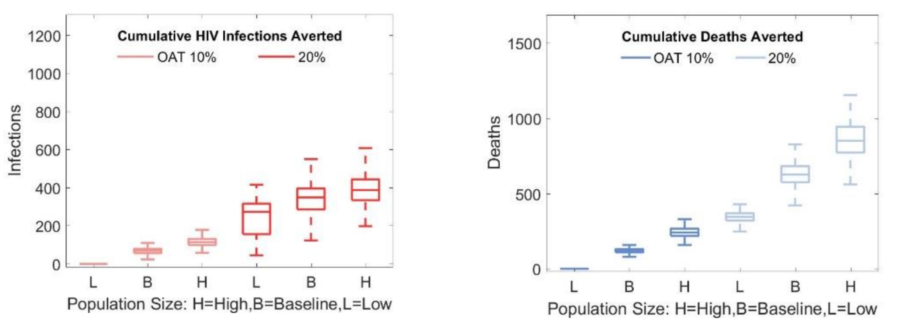
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

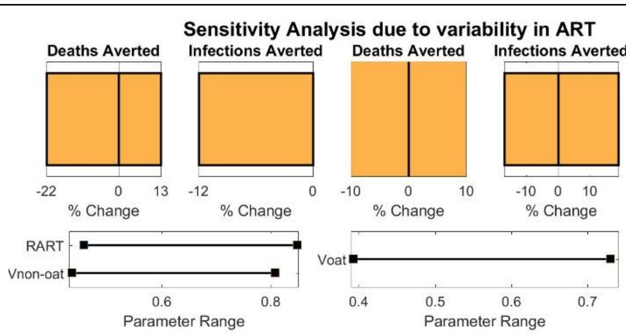
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



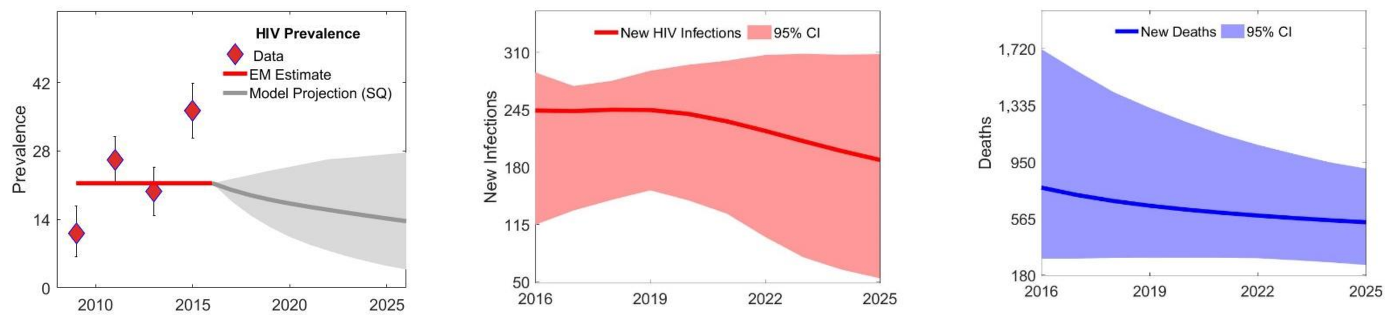
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

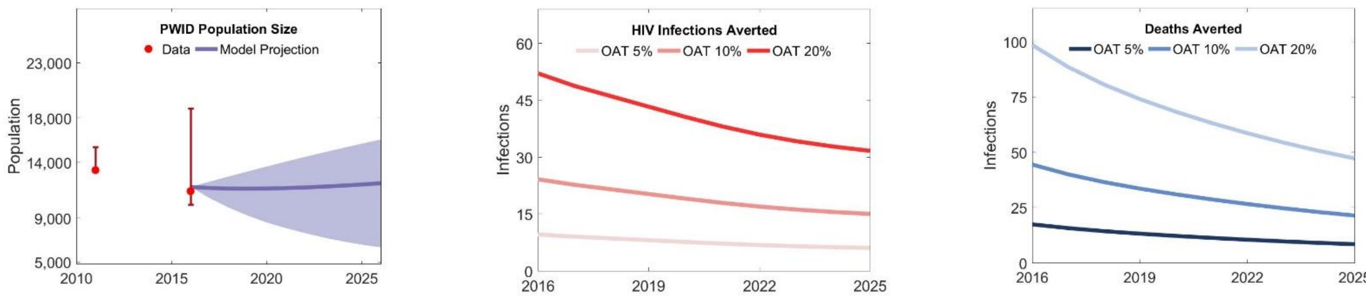
Figure S9. Region: **Cherkasy**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



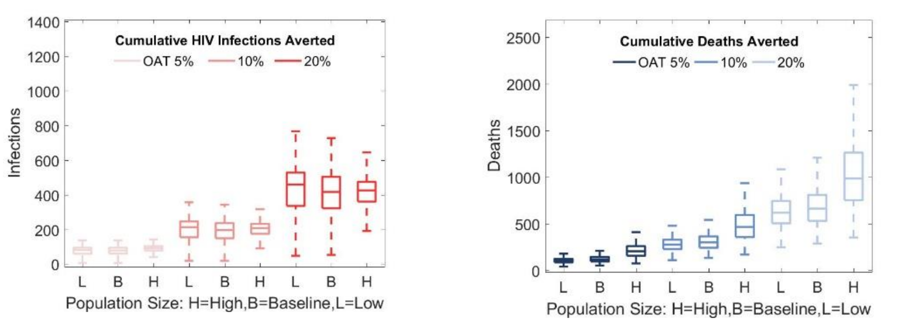
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

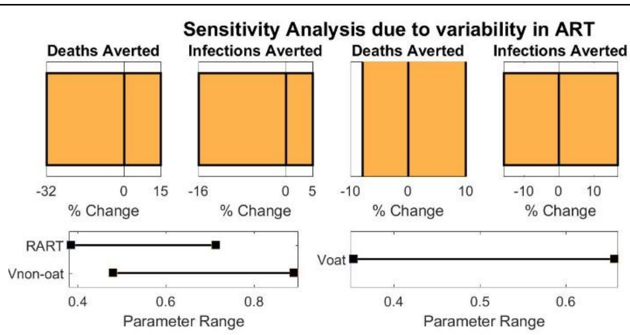
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



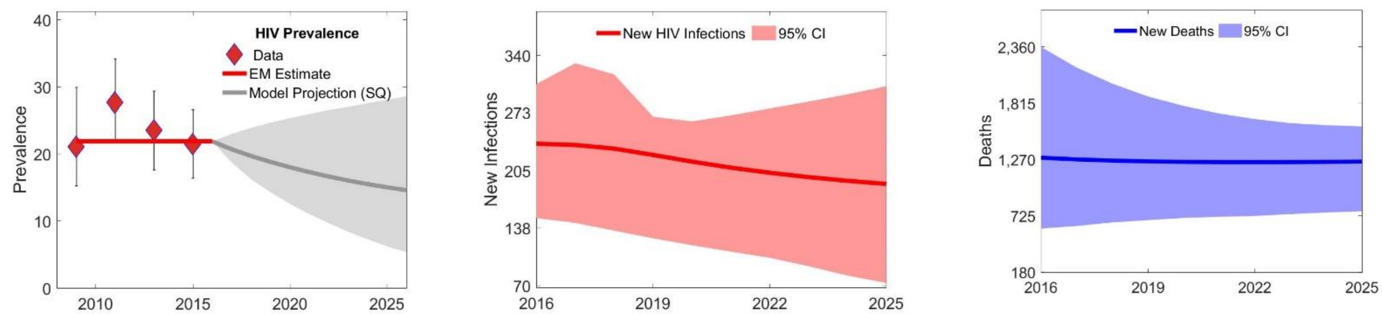
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

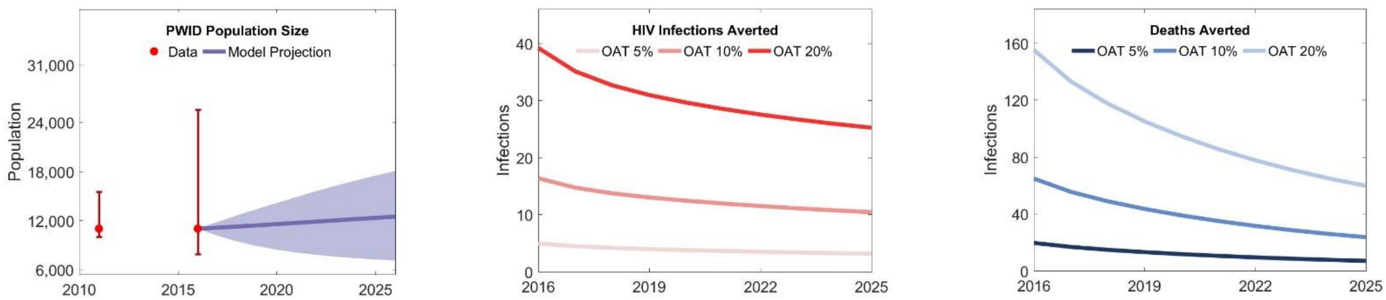
Figure S10. Region: **Lviv**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



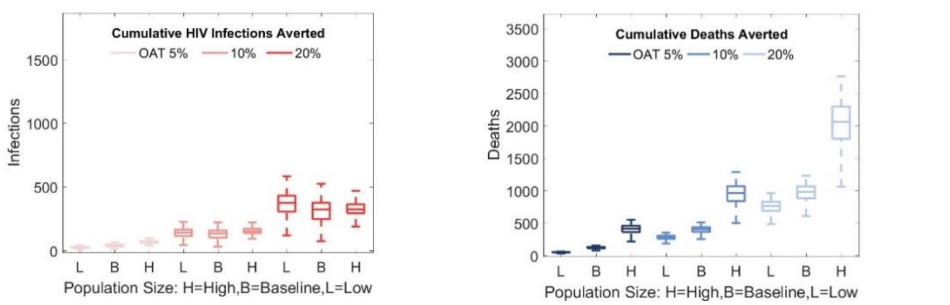
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

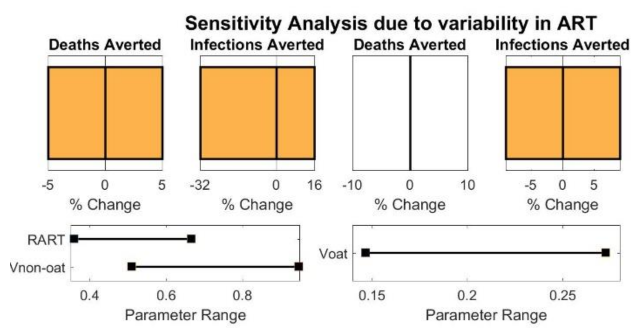
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



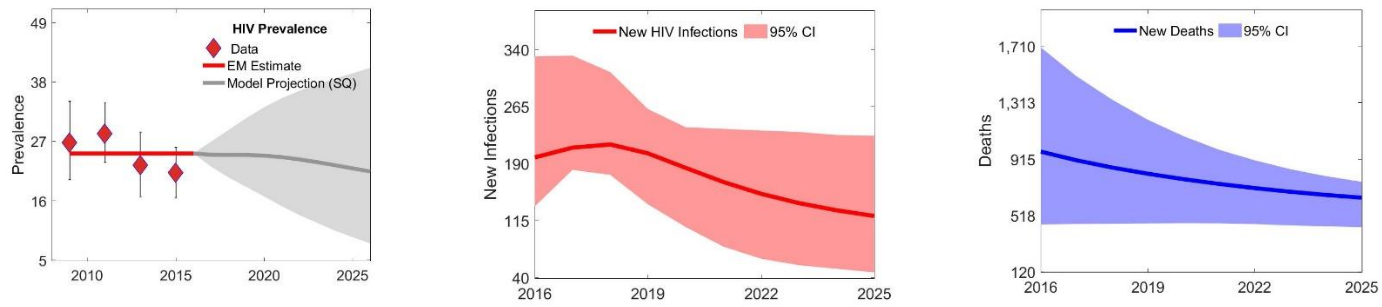
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

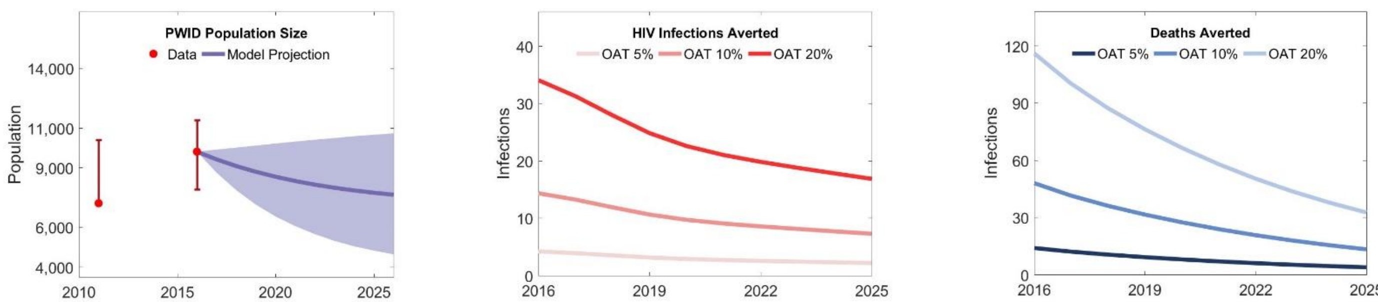
Figure S11. Region: **Kherson**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



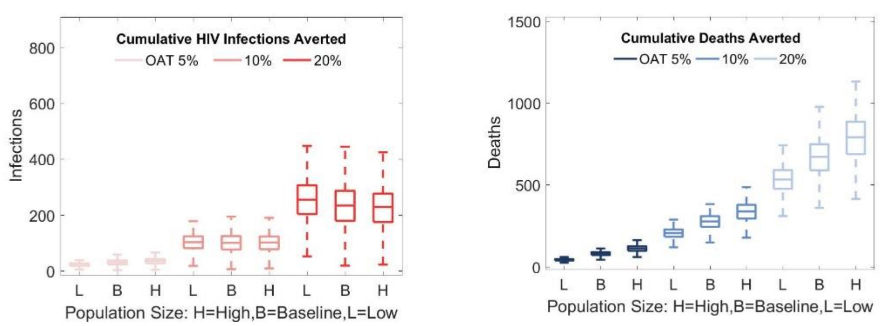
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

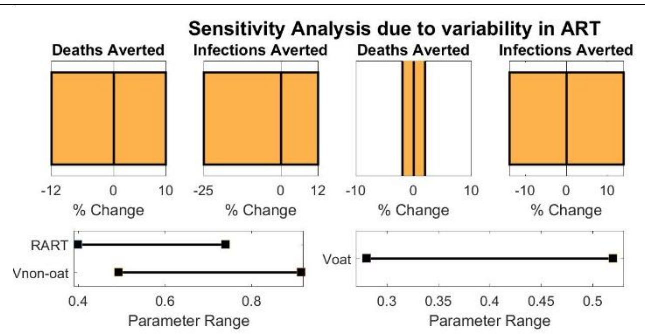
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



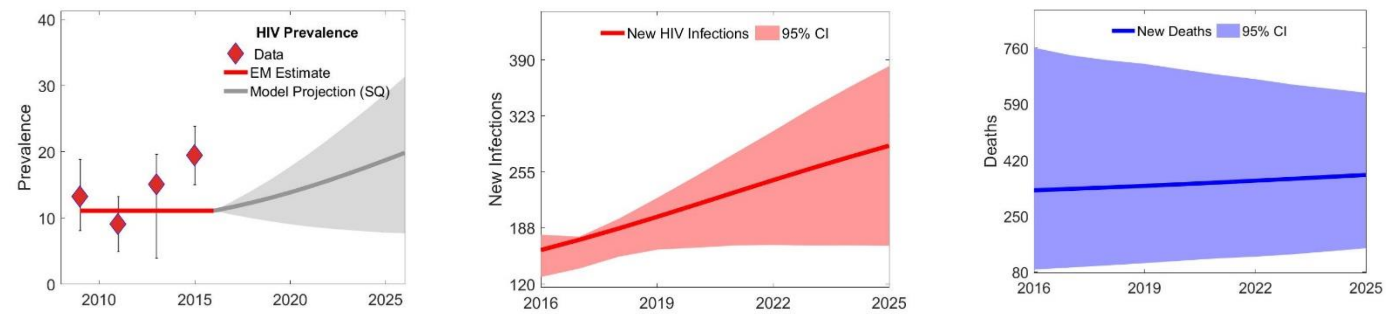
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

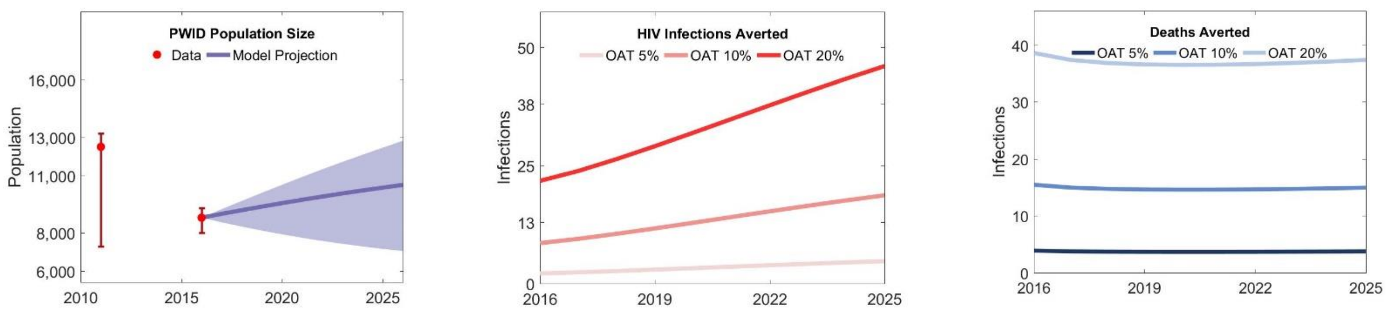
Figure S12. Region: **Kirovohrad**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



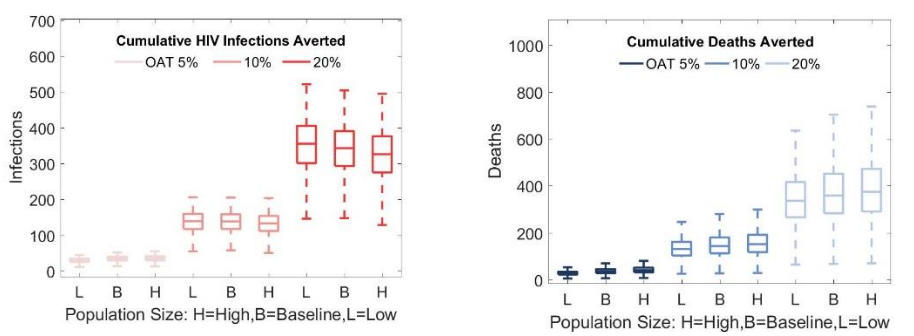
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

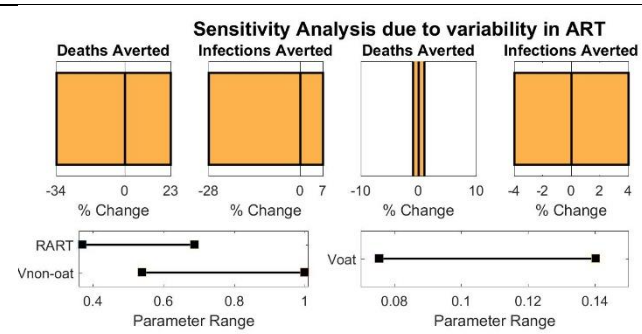
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



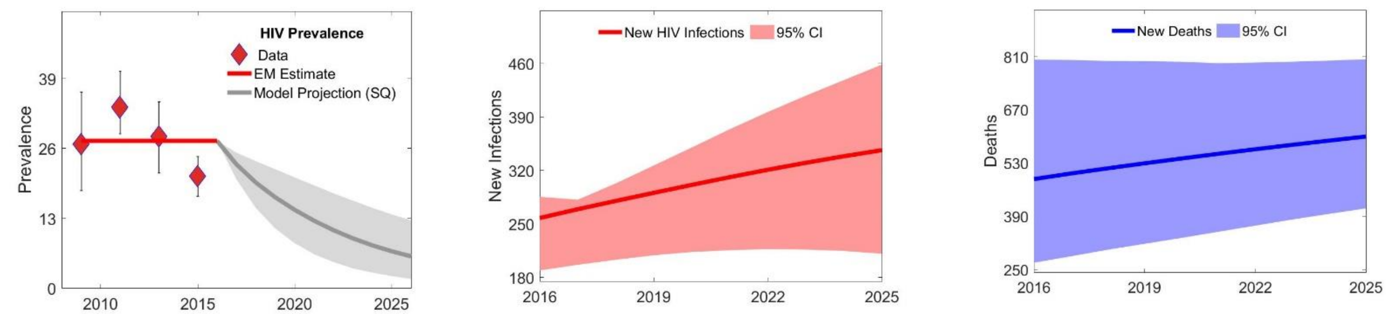
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

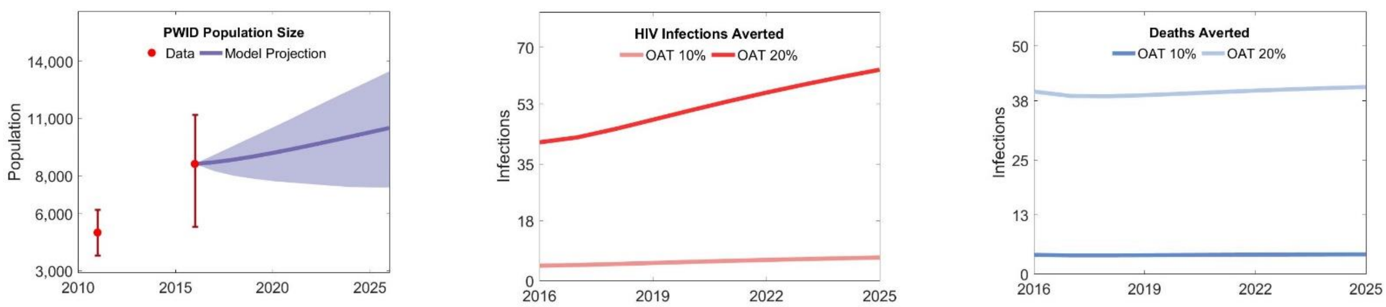
Figure S13. Region: **Khmelnytskyi**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



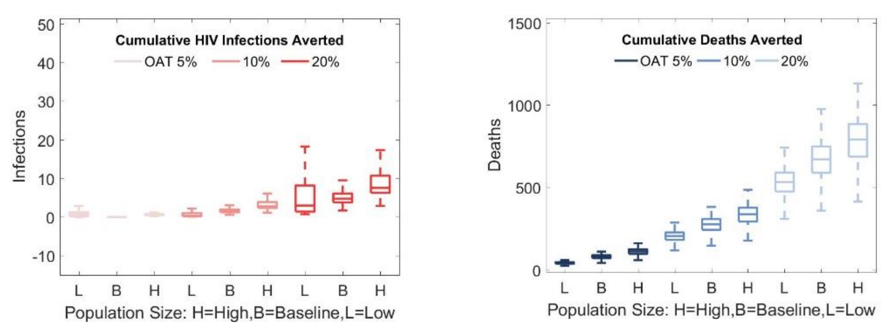
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

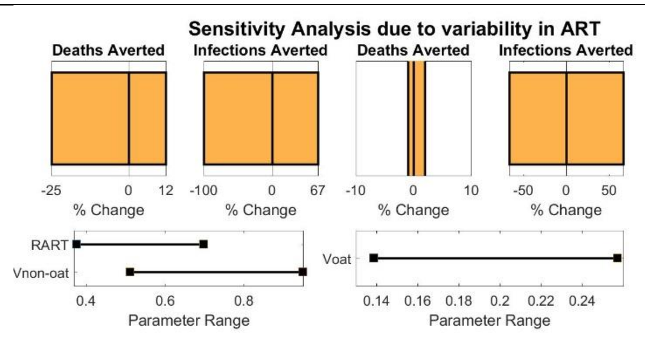
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



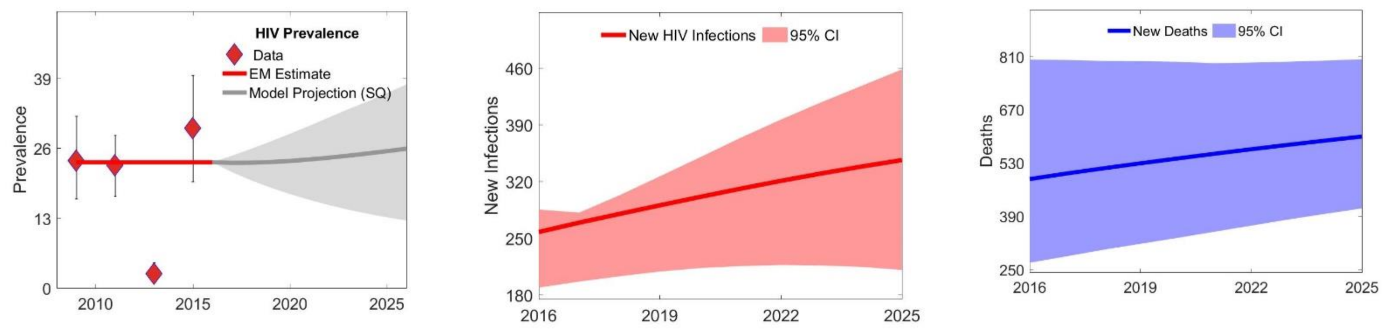
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

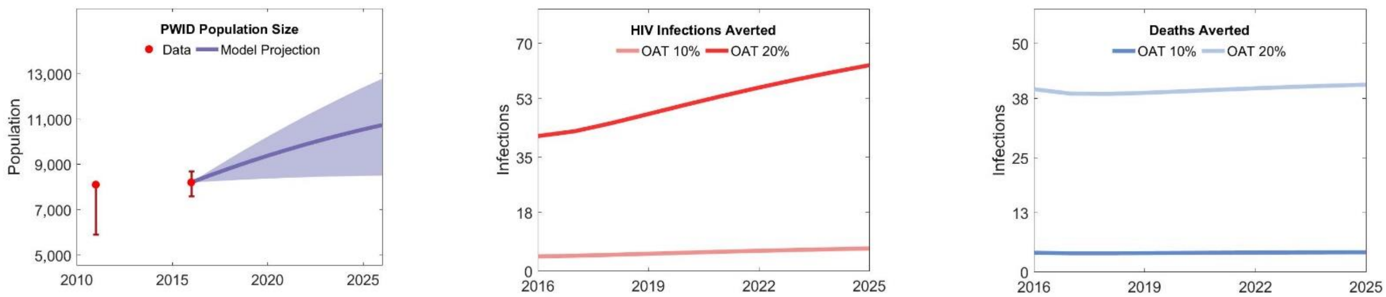
Figure S14. Region: **Poltava**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



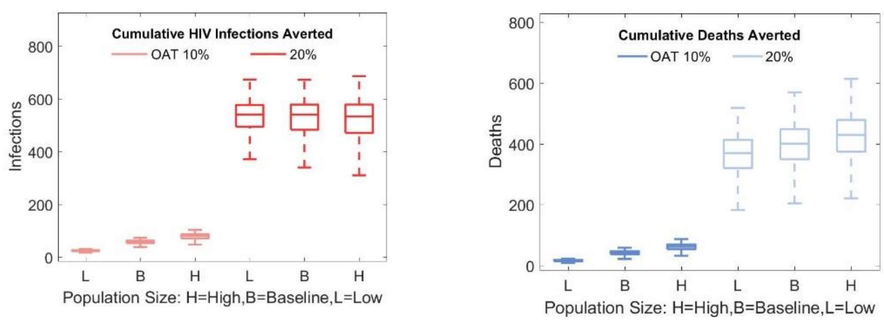
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

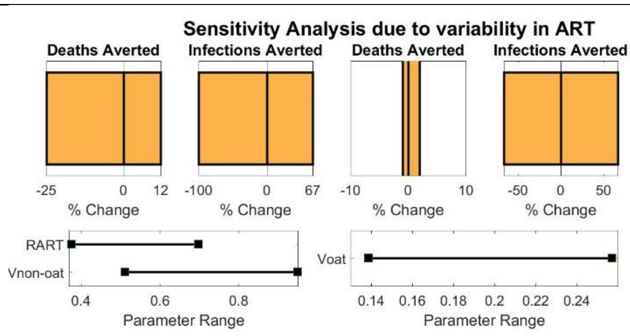
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



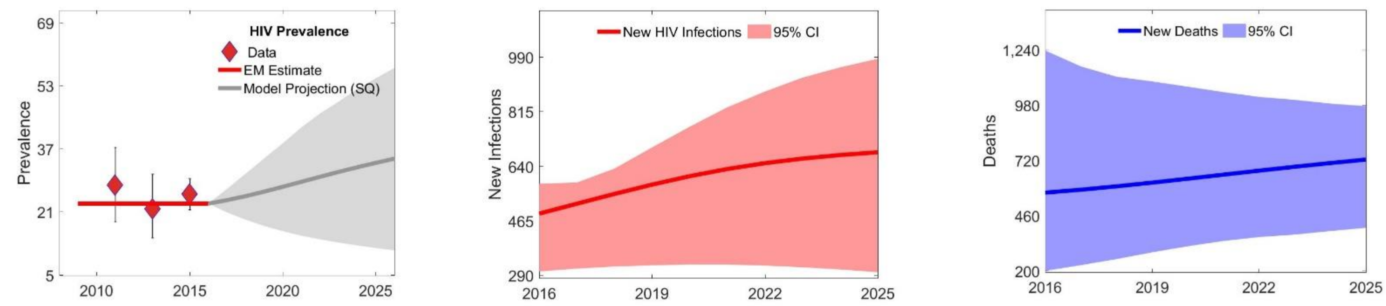
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

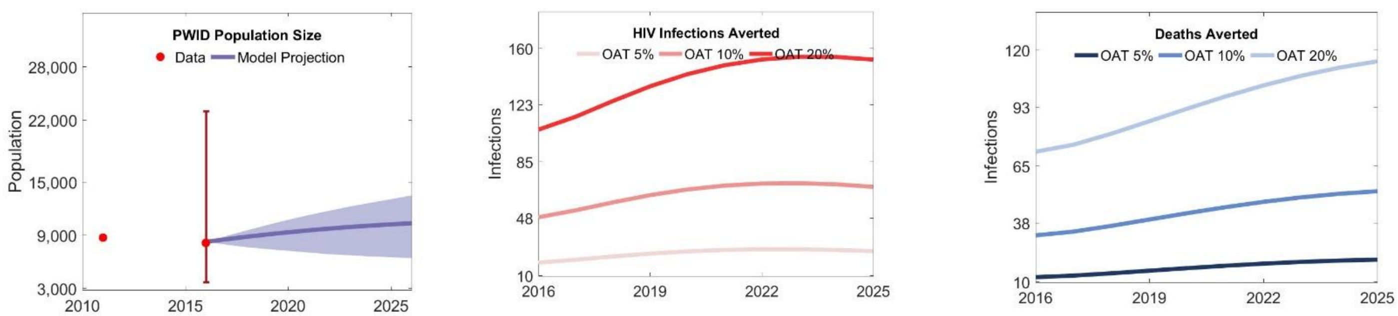
Figure S15. Region: **Kyiv Oblast**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



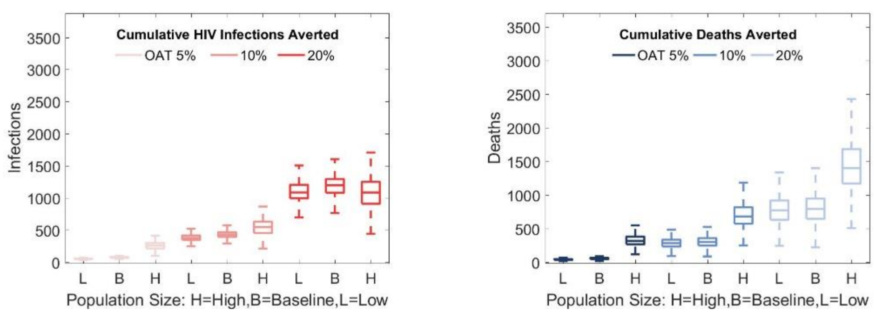
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

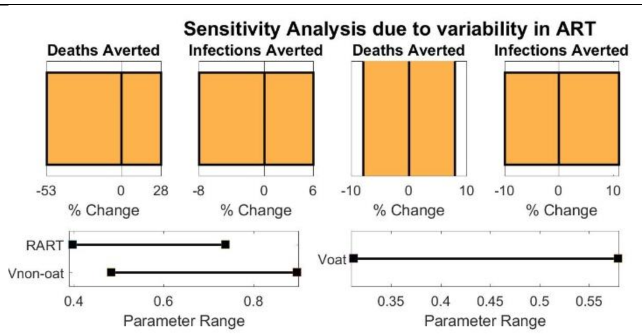
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



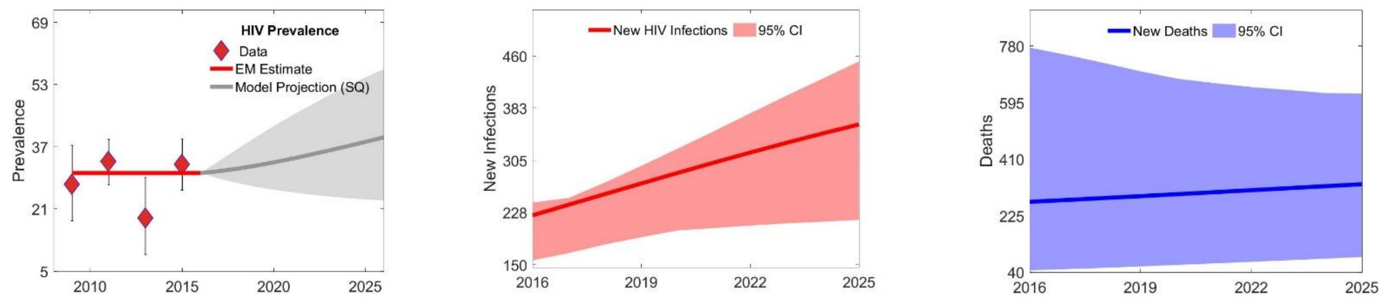
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

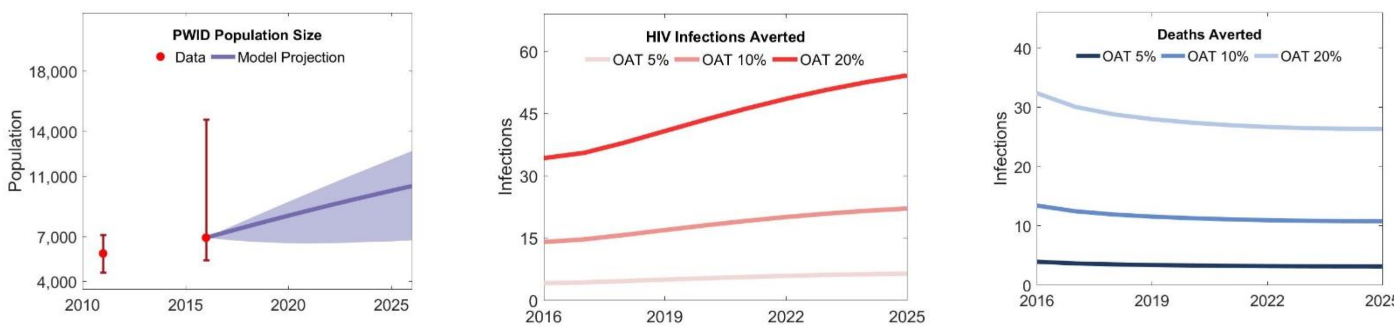
Figure S16. Region: **Chernihiv**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



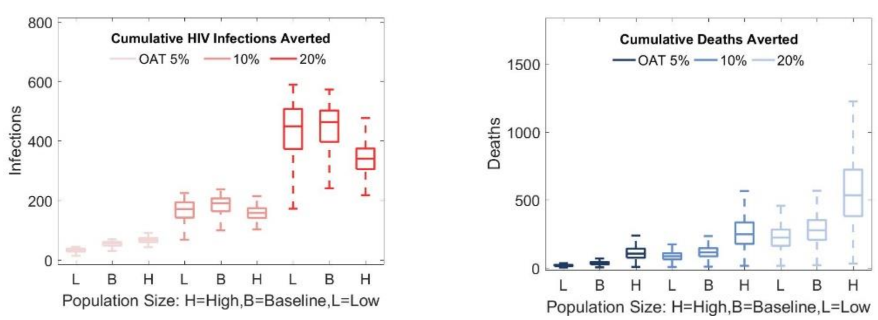
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

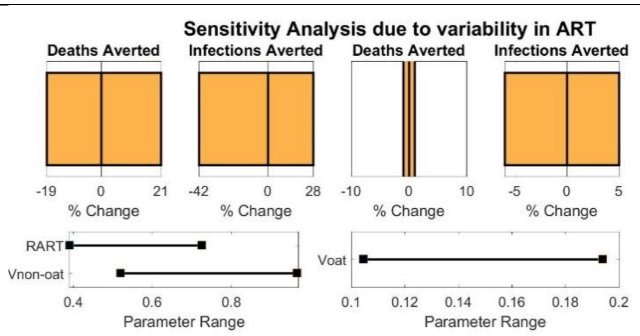
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



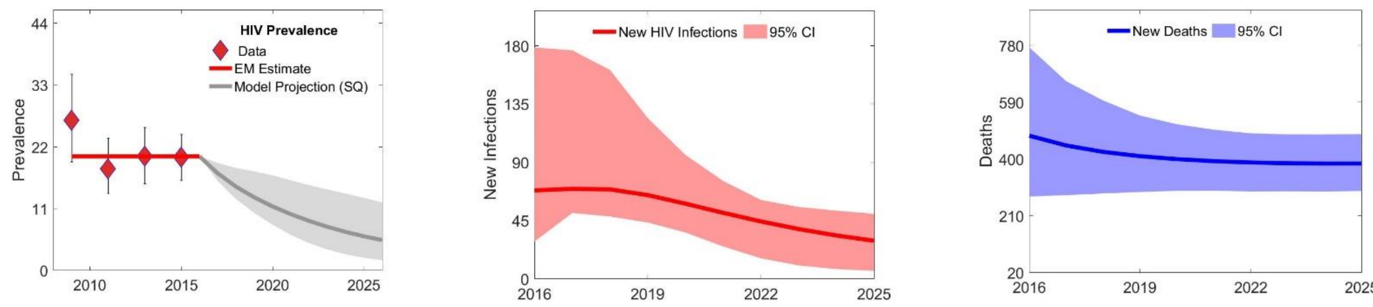
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

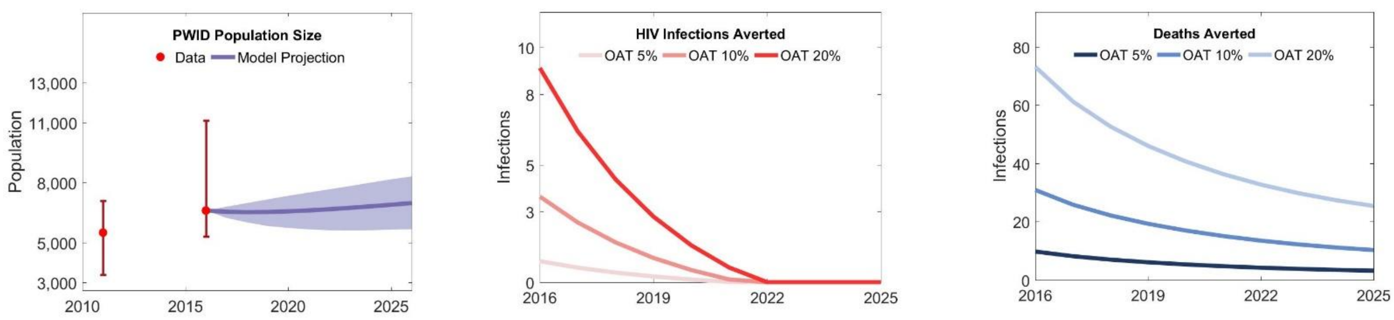
Figure S17. Region: **Volyn**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



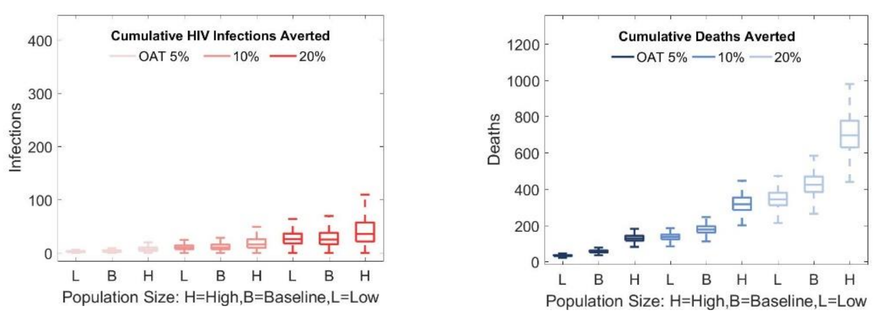
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

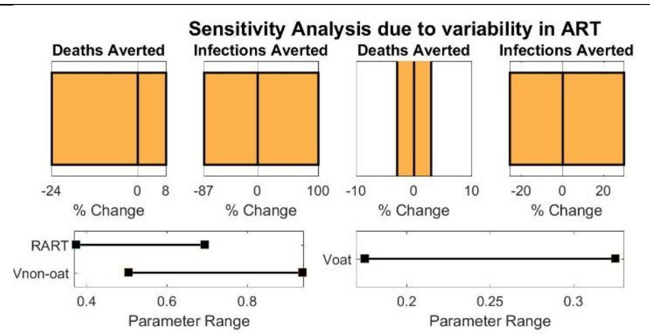
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



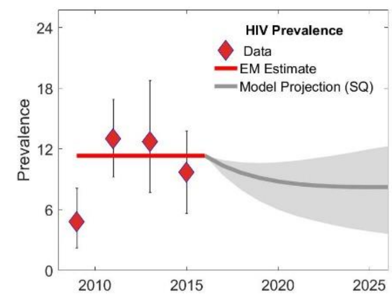
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

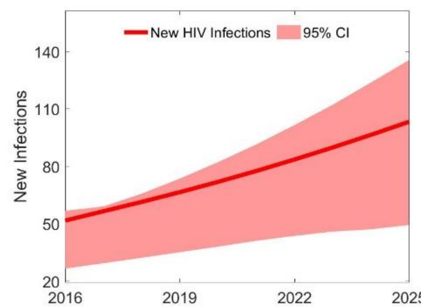
ART parameters are varied by +/- 30% of their observed base-value in each region

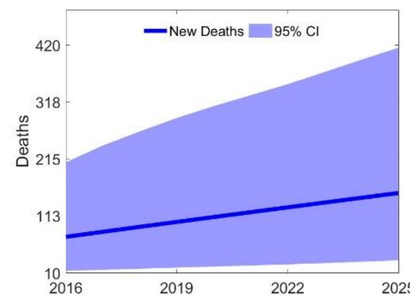
Figure S18. Region: **Vinnitska**

Data and Model Projections Under Different OAT Scale-up Scenarios

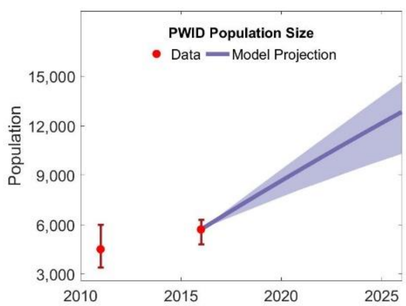
(A)

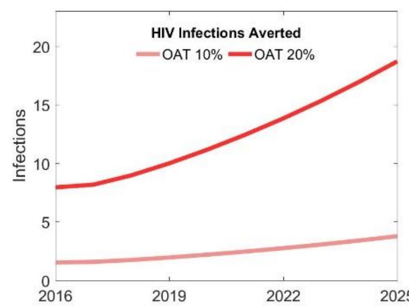


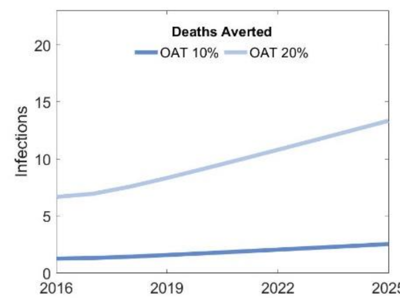




(B)



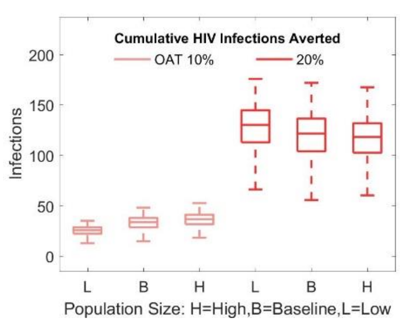


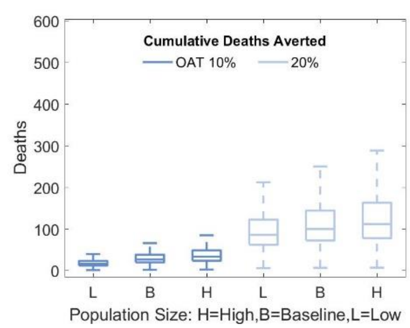


Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

(C)

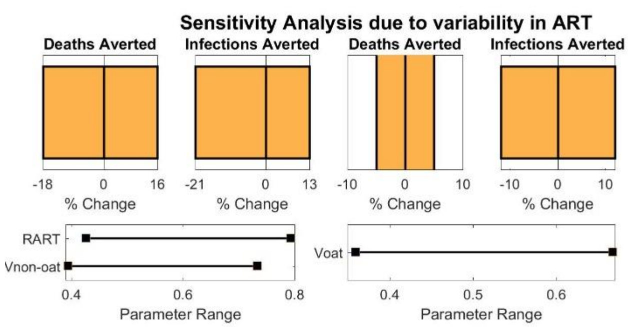




Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



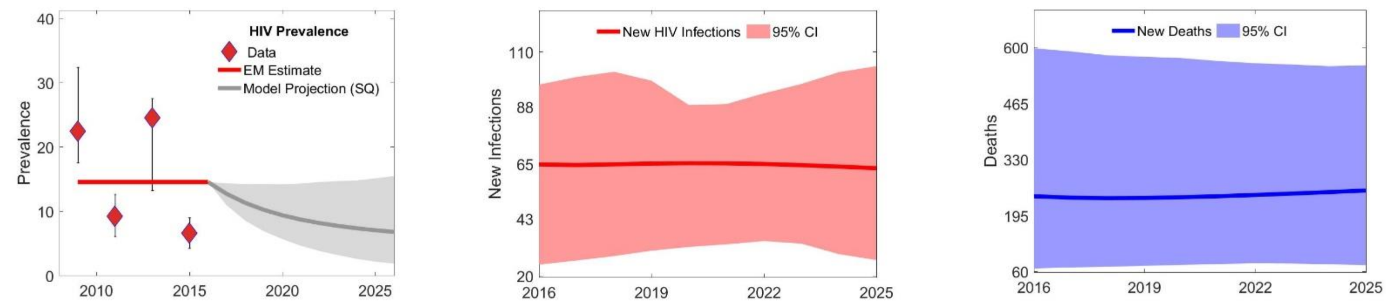
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

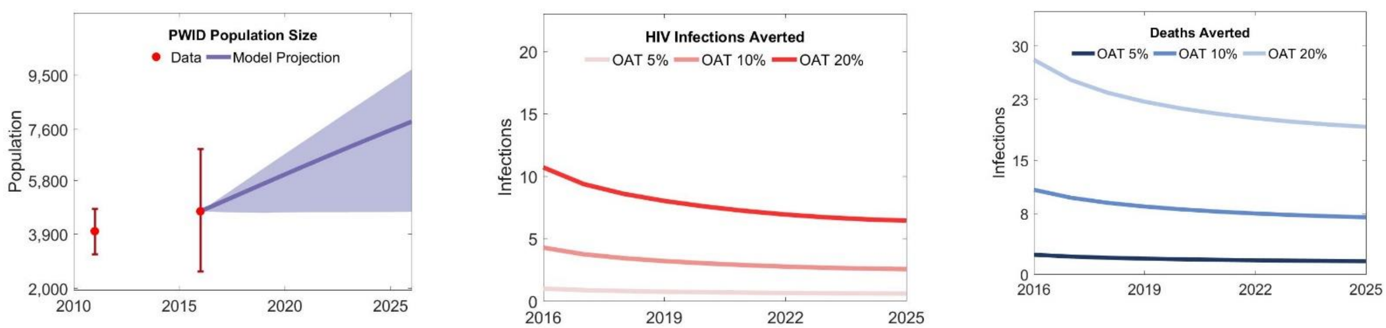
Figure S19. Region: **Rivne**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



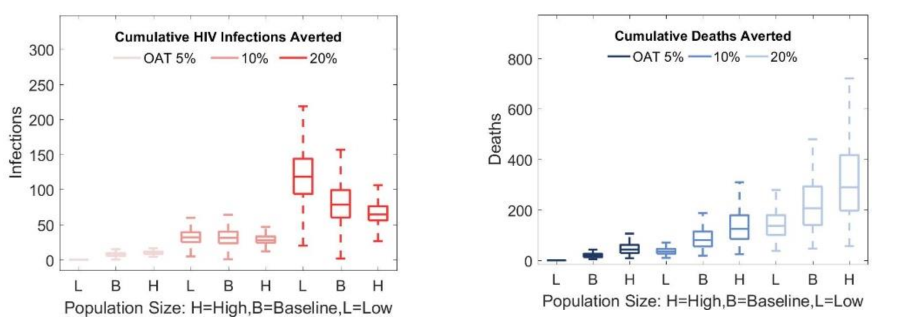
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

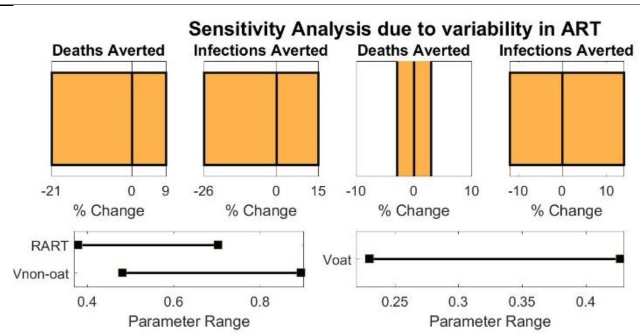
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



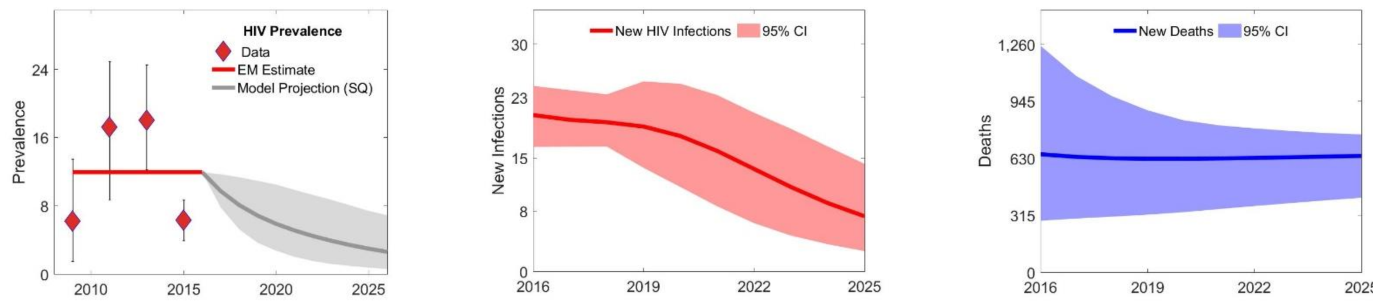
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

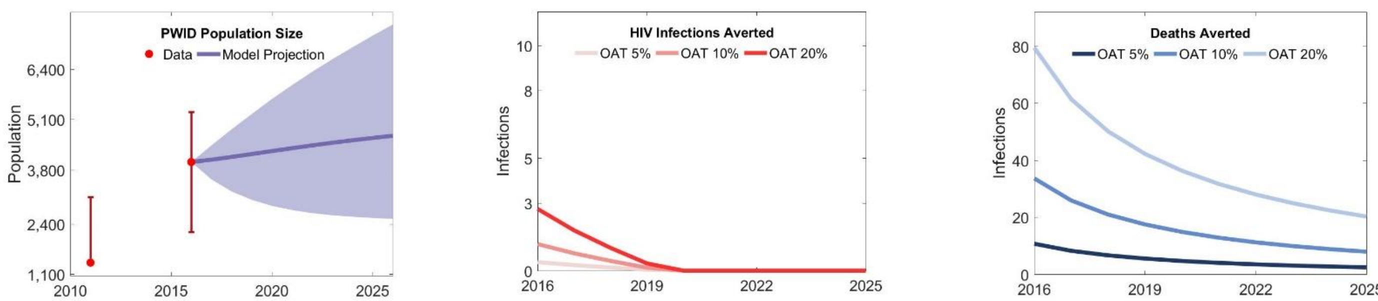
Figure S20. Region: **Ternopil**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



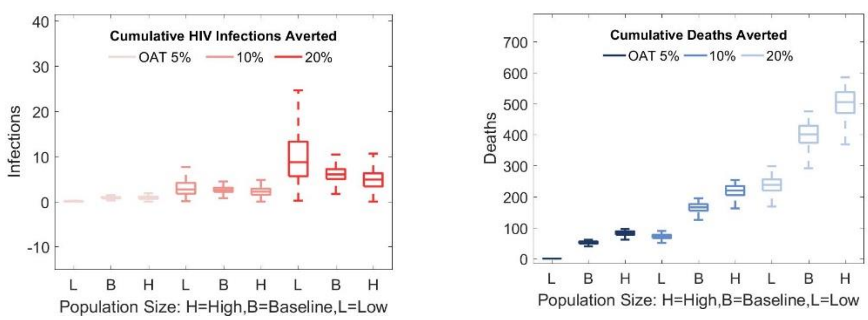
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

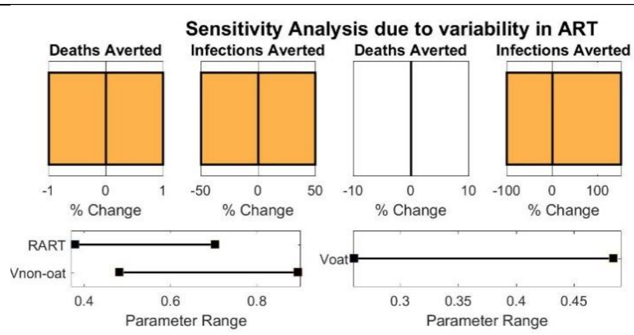
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



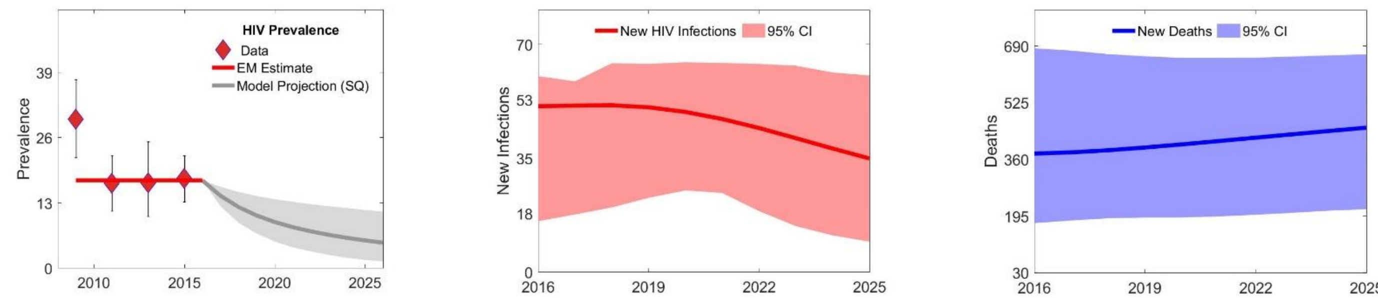
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

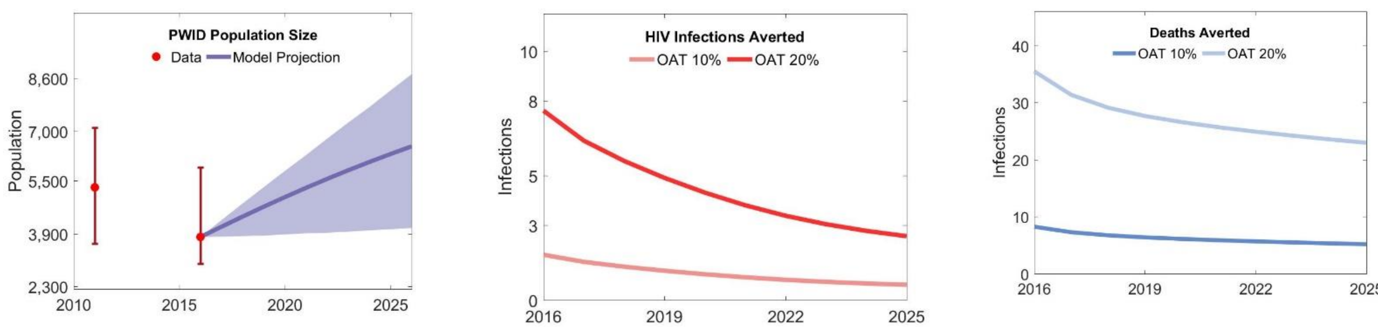
Figure S21. Region: **Ivano-Frankivsk**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



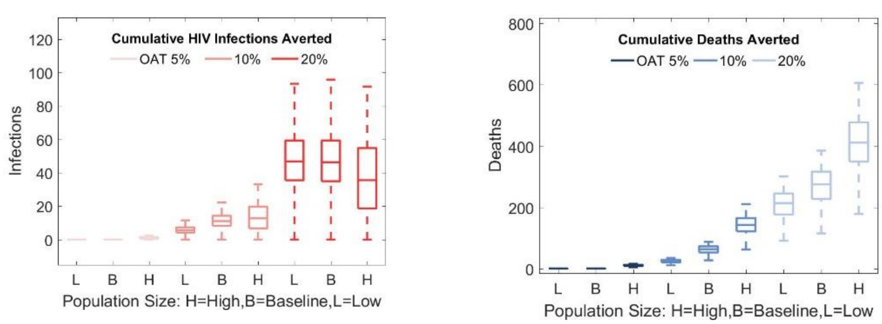
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

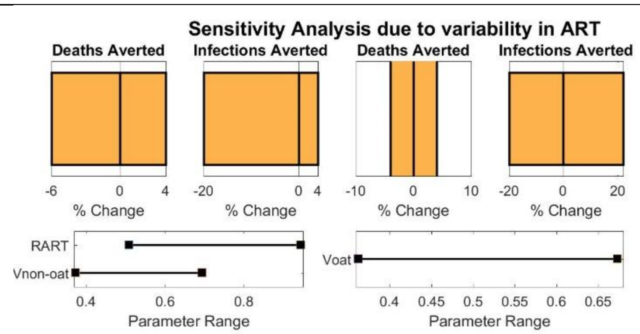
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



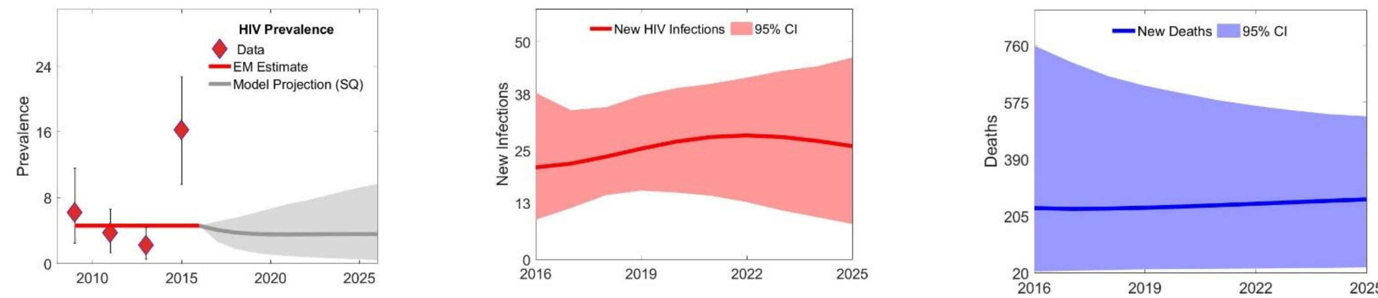
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

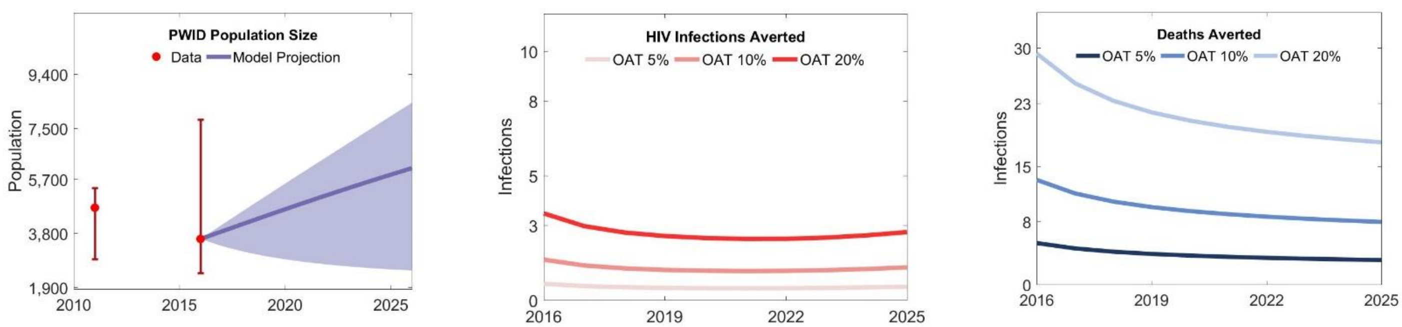
Figure S22. Region: **Chernivtsi**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



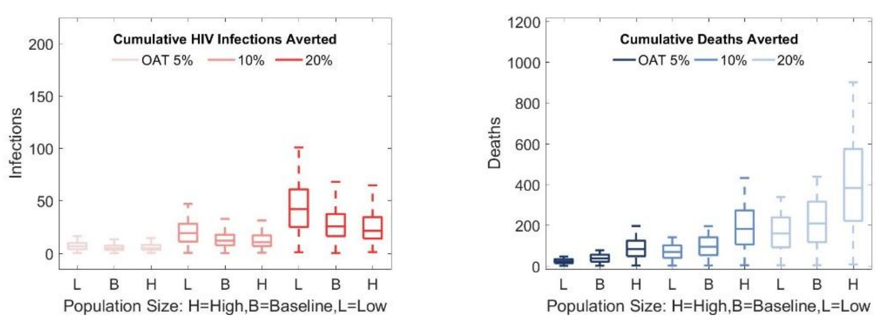
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

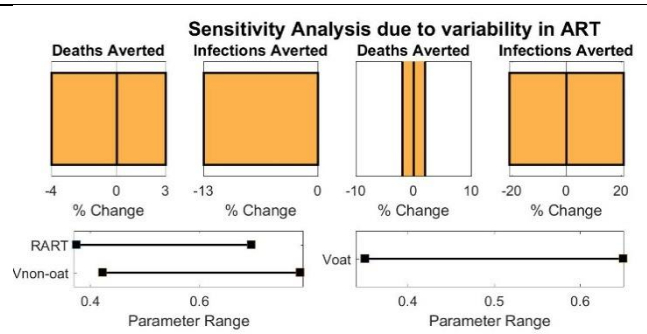
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



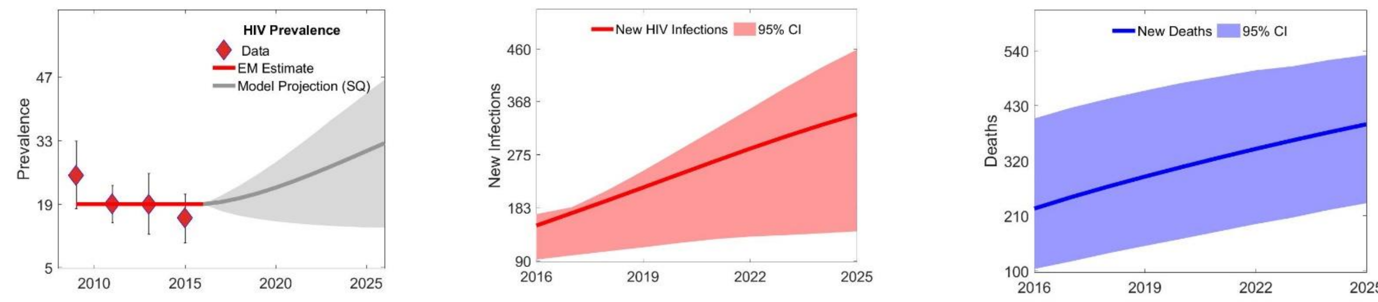
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

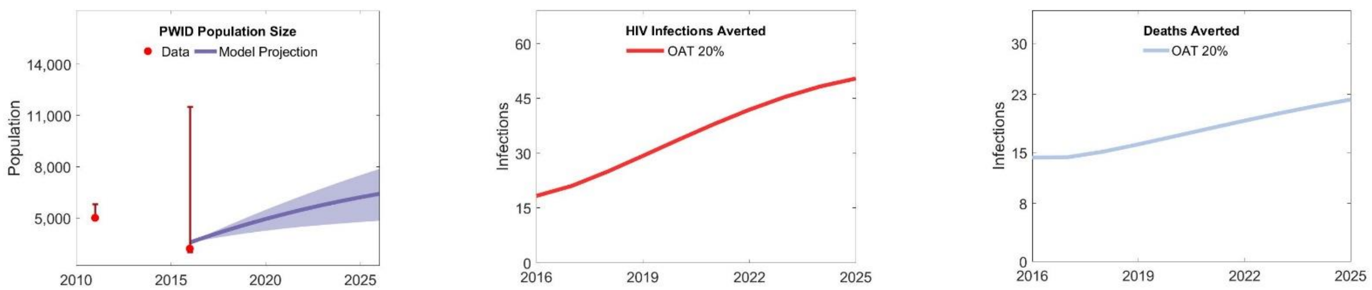
Figure S23. Region: **Zhytomir**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



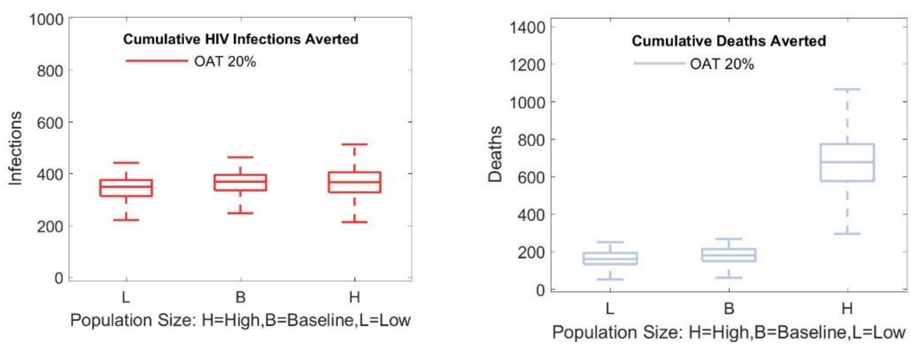
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

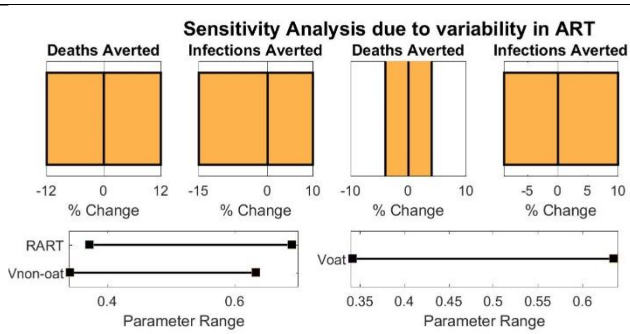
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



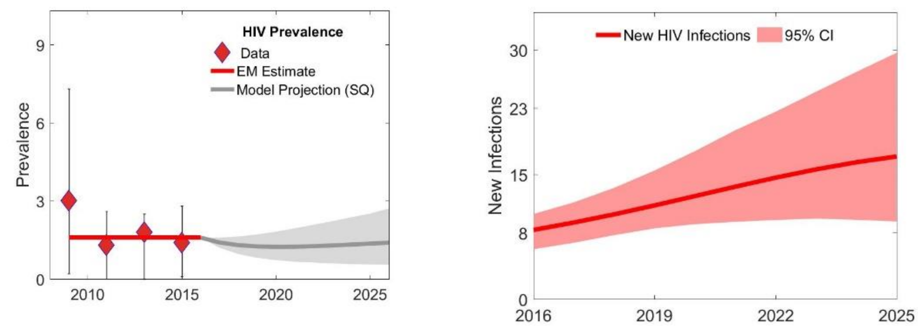
Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

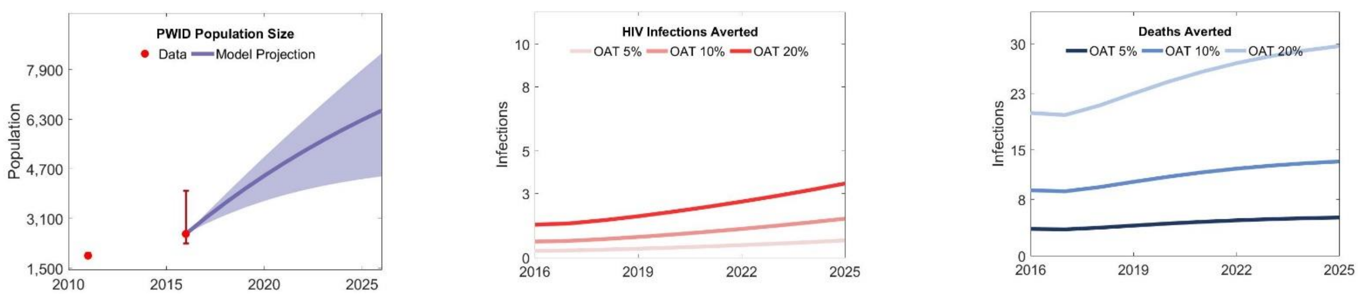
Figure S24. Region: **Zakarpattia**

Data and Model Projections Under Different OAT Scale-up Scenarios

(A)



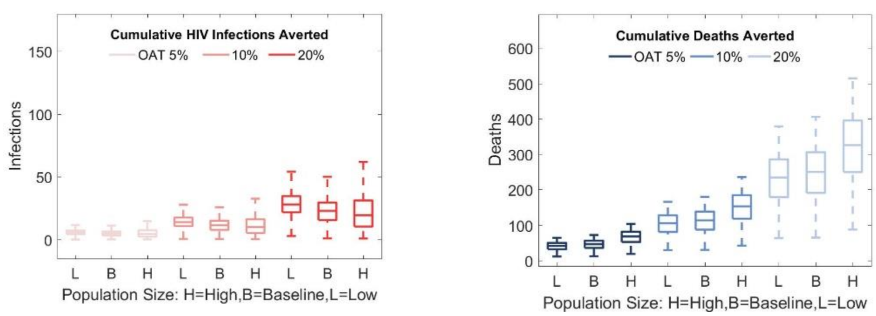
(B)



Footnote (A/B): In the projection of status quo, the line represents the mean; the shaded region - 95% confidence interval. EM stands for expectation maximization; (B) The circle represents point estimate for population size; error bar – max/min range.

Sensitivity Analysis: Population Size and ART

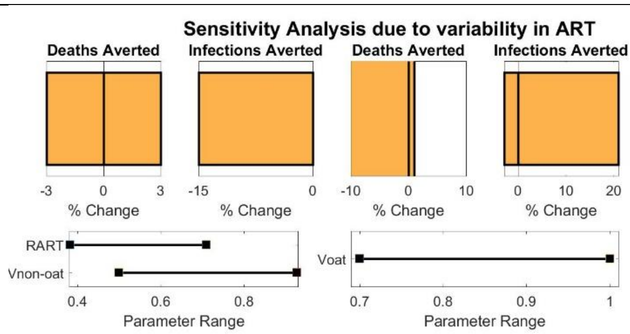
(C)



Note (C): Population size of PWID was varied based on the max/min (H/L) range published by AIDS Alliance and compared to baseline model (B);

Boxplots indicate the median, 25th and 75th quartiles, while whiskers – outliers

(D)



Note (D): V - probability of viral suppression among HIV+ PWID, with subscript indicating OAT/Non-OAT; RART – proportion of PWID receiving ART among non-OAT, HIV+ PWID;

ART parameters are varied by +/- 30% of their observed base-value in each region

Figure S27: All Regions Combined - Sensitivity Analysis with varying Population Size

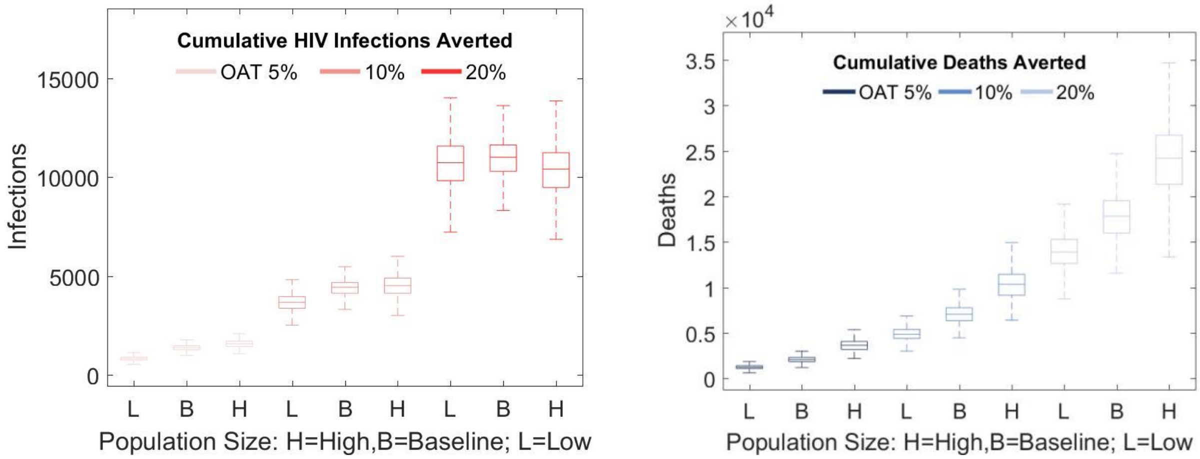
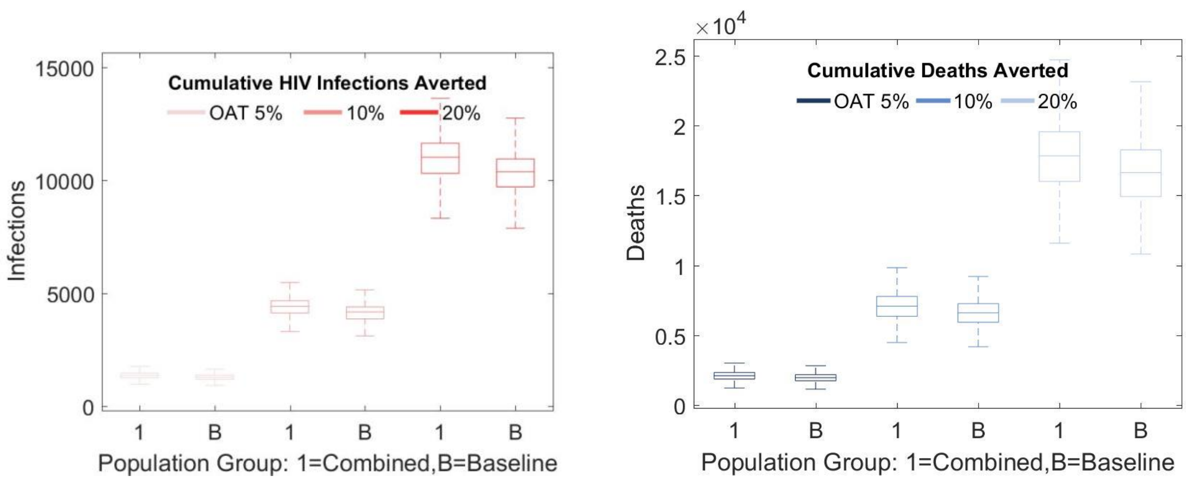


Figure S28: Sensitivity Analysis Based on Reducing Number of Population Compartments



Note: We performed additional sensitivity analysis, in which the MSM and non-MSM groups were combined into a single compartment and the models were re-calibrated.

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