

# What will it take to ‘End the HIV epidemic in the US’: An economic modeling study in 6 cities

**Bohdan Nosyk, PhD**

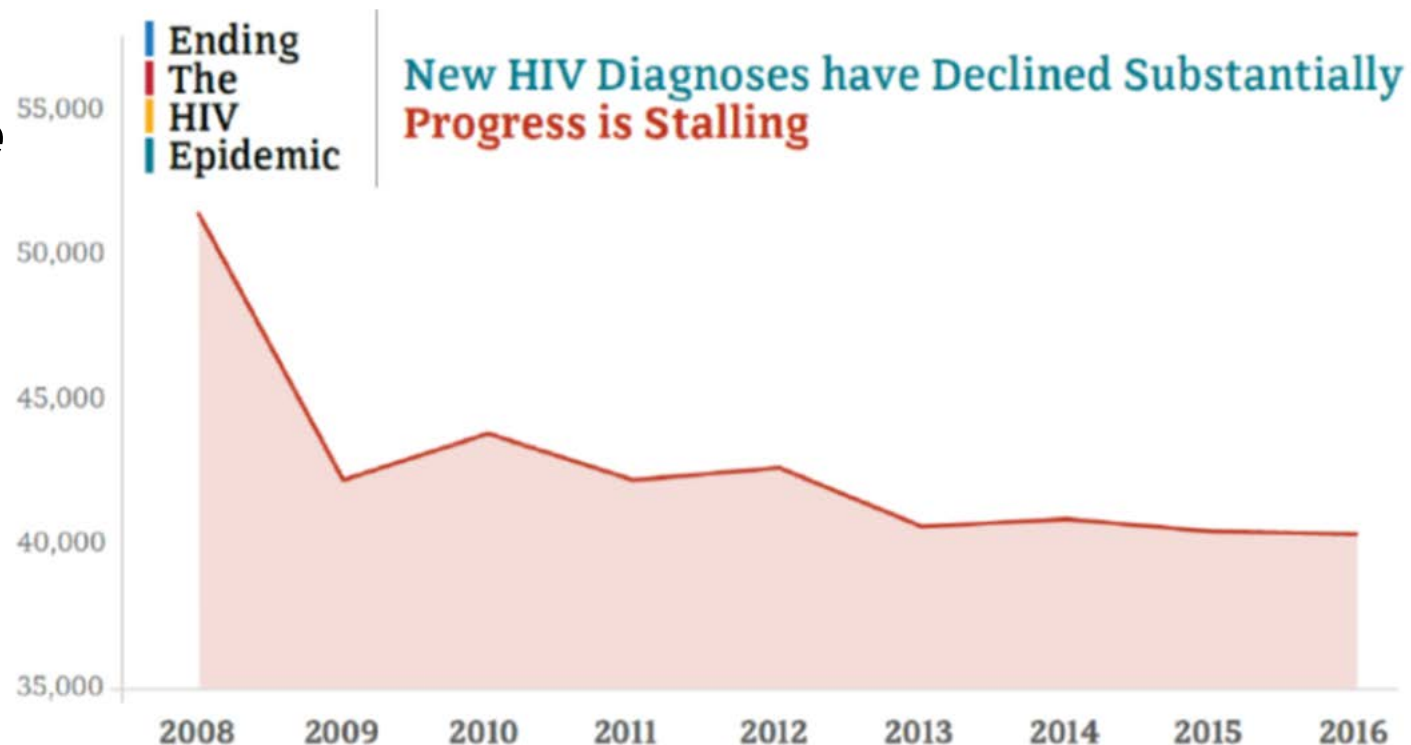
**Associate Professor, St. Paul’s Hospital Canfar Chair in HIV/AIDS Research  
Faculty of Health Sciences, Simon Fraser University**

**On behalf of the Health Economic Research Unit at the BC Centre for Excellence in HIV/AIDS and the Localized Economic Modeling Group.**

**R01 DA041747. PI: Nosyk B; Co-I: Schackman BR, Gebo K, Metsch L, Feaster D, Kirk G, Golden M, Mehta S, Shoptaw S, Strathdee S, Dombrowski J, Montaner JSG, Small W, Poon AFY, Del Rio C. Localized economic modeling to optimize public health strategies for HIV treatment and prevention. National Institutes on Drug Abuse; RFA-DA-16-001.**

# Background

- Despite numerous successes in the fight against HIV/AIDS and a \$20B annual investment in the US, progress is stalling
- Evidence-based interventions available to ***Protect, Diagnose*** and ***Treat*** HIV/AIDS
- Implementation has been suboptimal, with wide disparities in access across regions, ethnic groups.



# Background

- On February 5, 2019 at the State of the Union Address, the President of the United States announced the intention to end the HIV epidemic in the US by reducing new infections by 75% within 5 years and by 90% within 10 years.
- To reach these goals, the Department of Health and Human Services is proposing to target 48 counties plus Washington, DC and San Juan, Puerto Rico and 7 Southern States
- \$267 million in new funding allocated in 2020; additional \$117M through DHHS

# Background

- While investments are front-loaded, the benefits of HIV/AIDS treatment and prevention initiatives are accumulated over the long-term.
- Given the need to project into the future with incomplete information, modeling is the only way to obtain an estimate of the full extent of costs and health benefits of HIV treatment and prevention interventions compared to other more-or less resource-intensive counterfactuals.
- Health economic modeling can help us figure out what interventions work best for each epidemiological context.

# Objective

- Considering 16 evidence-based interventions to diagnose, treat and prevent HIV infection, we aimed to identify the highest-valued combination implementation strategies to reduce the public health burden of HIV/AIDS in six US cities.
- Value judged on the basis of quality-adjusted life years
  - International consensus as best practice
  - Captures, weighs benefits of reduced morbidity, mortality and transmission
  - Focus on equity, maximizing population health

# A primer on health economic evaluation

- The comparative analysis of alternative courses of action in terms of both their costs and consequences.
- Concerned with **efficiency**, not just **effectiveness**
- Economic evaluation is about informing decisions on how to focus resources: **Evidence-based decision-making**
- **Our primary outcome:** the incremental cost-effectiveness ratio (ICER):

$$ICER_{a,b} = \frac{Cost_a - Cost_b}{Eff_a - Eff_b}$$

# Orientation

- Core principle: maximize population health
- To do this, we use quality-adjusted life years (QALYs) in the denominator of our ICER.
- The QALY a measure that captures improvements in both ***morbidity*** and ***mortality***
- Equity principle: QALYs gained across disease areas are of equal value
- QALYs give priority to interventions that offer ***more time spent in good health.***

# Our focal cities: Home to 24.1% of the US population of people living with HIV/AIDS



## Total adult 15-64 Population (% projected change to 2040)

Total population (2016)	3,812,143 (37%)	1,874,601 (-1%)	6,964,983 (-2%)	1,821,311 (16%)	5,865,683 (3%)	1,503,497 (15%)
-------------------------	-----------------	-----------------	-----------------	-----------------	----------------	-----------------

## Adult 15-64 Population by race/ethnicity (% projected change in proportion by 2040)

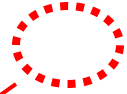
Black / African American	1,336,469 (-1%)	553,665 (5%)	568,815 (-1%)	296,354 (-2%)	1,304,687 (-1%)	95,550 (1%)
Hispanic / Latinx	391,265 (10%)	102,495 (3%)	3,385,948 (4%)	1,246,583 (7%)	1,703,286 (4%)	137,818 (7%)
Non-Hispanic White and others	2,084,409 (-9%)	1,218,441 (-8%)	3,010,220 (-3%)	278,374 (-5%)	2,857,710 (-3%)	1,270,129 (-8%)

## People Living with HIV (rate/100,000) †

Prevalence	31,961 (670)	16,931 (718)	48,100 (564)	26,128 (1,120)	117,260 (959)	7,768 (312)
New diagnoses	1,618 (33)	441 (19)	1,720 (20)	1,150 (49)	2,608 (21)	248 (10)
National Rank <sup>Δ</sup>	2	25	27*	1	21*	75*



!"#\$%&'()\*+,-./:;<=>?@A



%, !-#. /"%"!<br/>:;<=>?@A



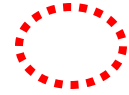
. "D-E, 3' -41\$E<br/>&OF5)G7-' ()\*H7-<br/>. E-I >99)H+



0#%\$12, 3"

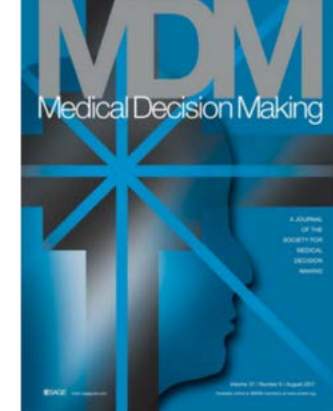
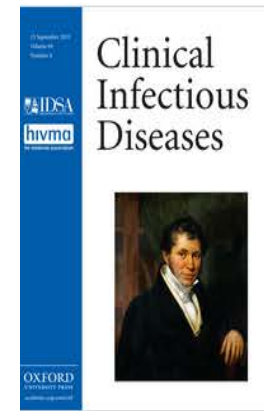


#\$%#. \$#-&45667-89:;<67-<br/>=>?5)7-/@()9??+



21# 21-&2(; A(B8; C9+

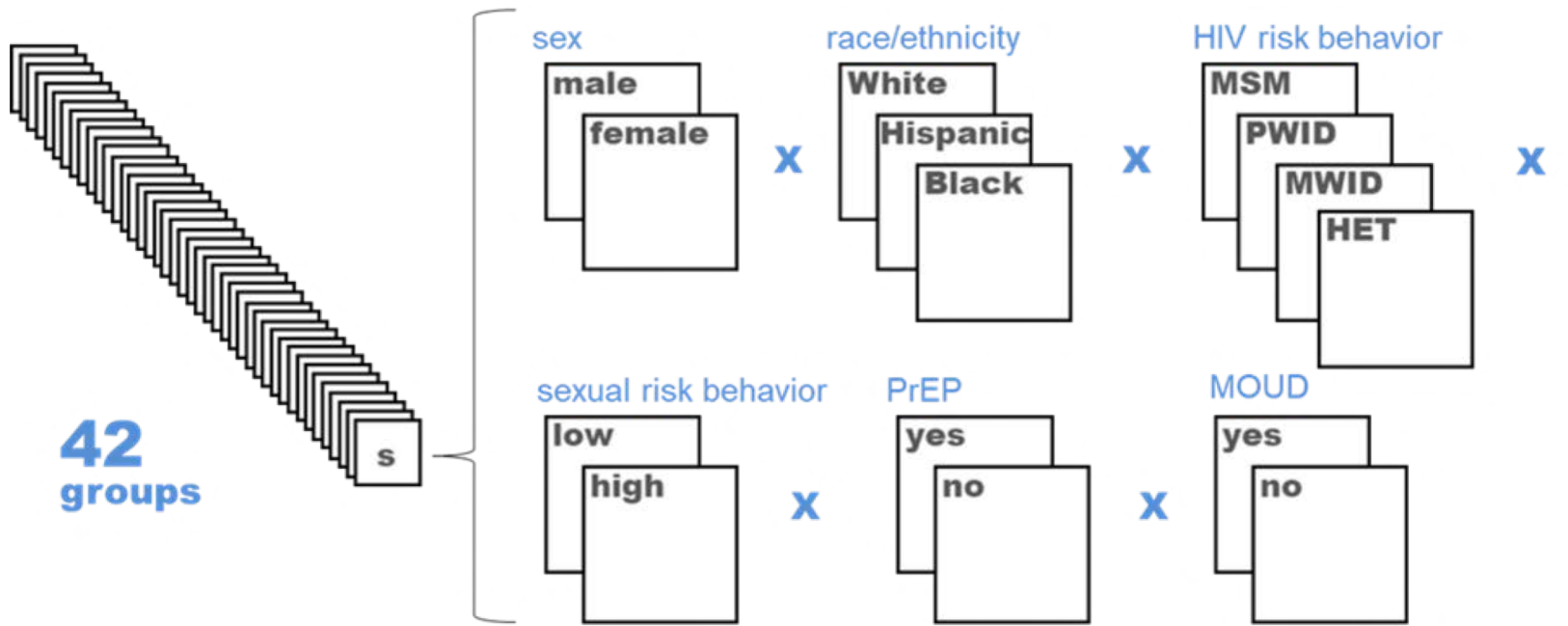
# Background Research



1. **Scientific Case** (Panagiotoglou et al, *AIDS Behav.* 2018;22(9):3071-3082)
2. **Evidence Synthesis** (Krebs et al, *PLoS One.* 2019;14(5):e0217559)
3. **Medical Care Costs** (Enns et al, *AIDS.* 2019;33(9):1491-1500)
4. **Disease progression, ART persistence** (Wang et al, *Lancet HIV.* 2019;6(8):e531-e539)
5. **Model Calibration and Validation** (Zang et al, *Med Decis Making.* 2020;40(1):3-16)
6. **Defining the 'status quo' comparator** (Nosyk et al, *Clin Infect Dis.* 2019;69(12):2195-2198)
7. **Defining the evidence-based interventions** (Krebs et al, *AIDS* 2020;34(3):447-458)
8. **What will it take to 'End the HIV Epidemic' in the US?** (Nosyk et al., *Lancet HIV*, 2020;7(7):e491-e503.)

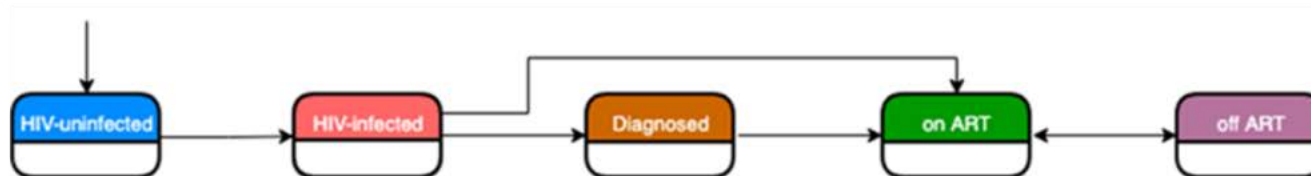
# Replicating Atlanta's HIV epidemic among adults aged 15 to 64

The population aged 15-64 was stratified according to:

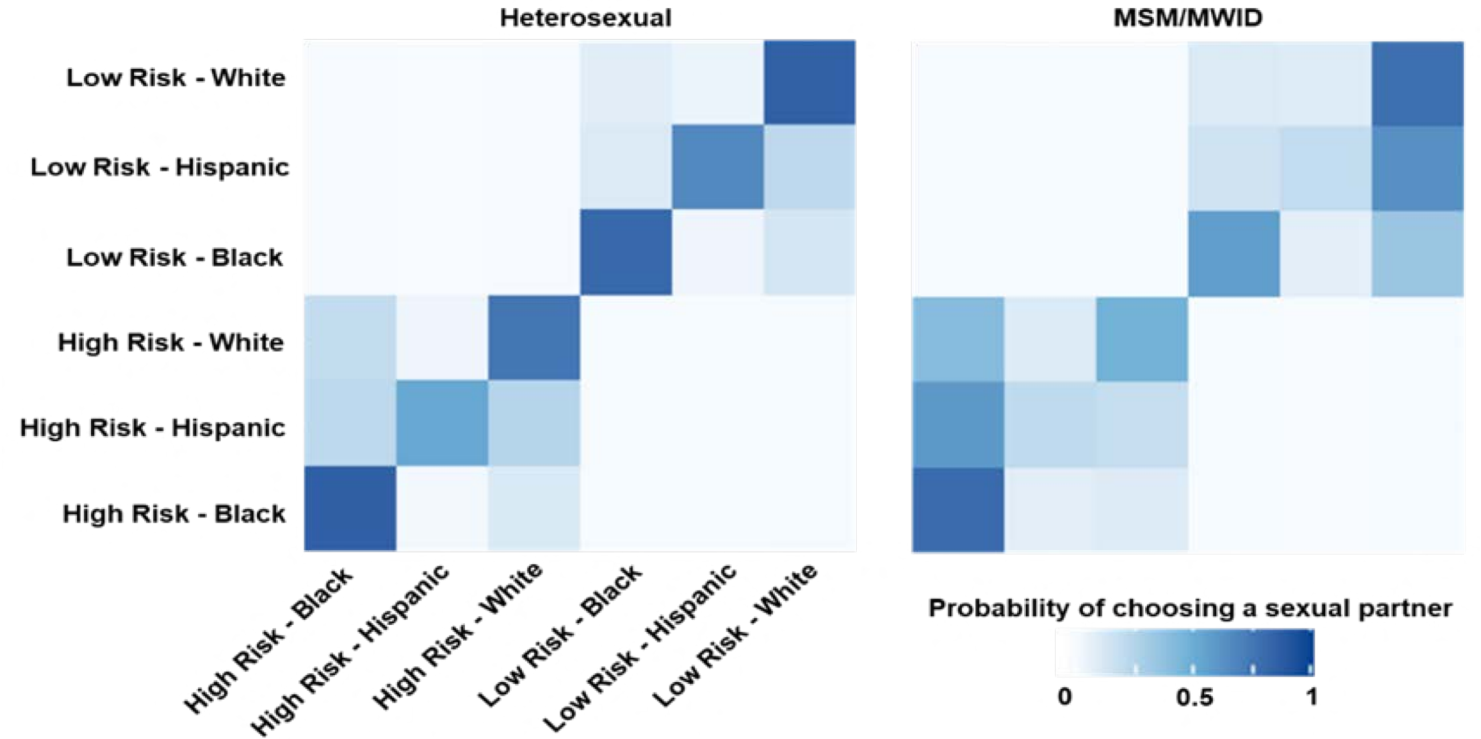
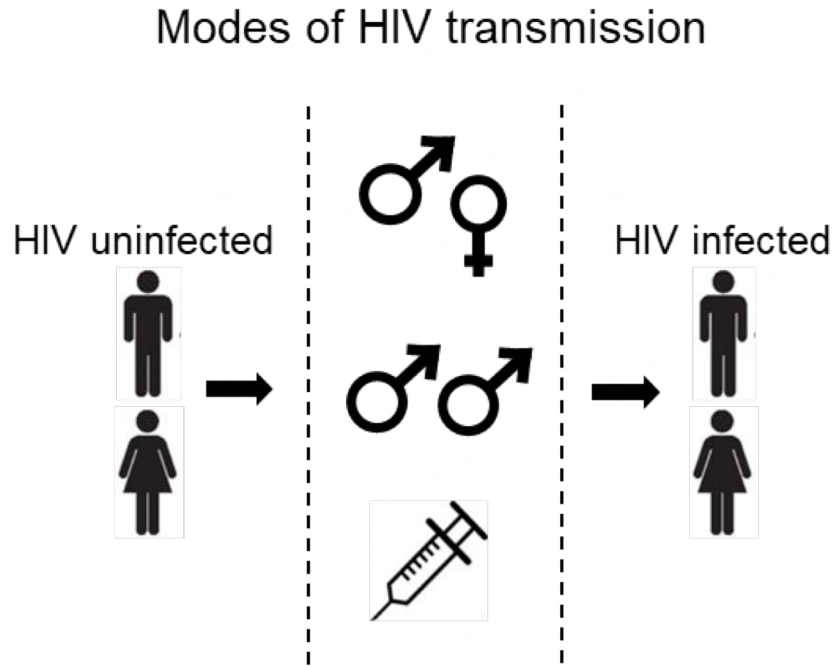


Health states were also separated by CD4 cell count among HIV-infected, acute HIV among newly infected individuals, and included HIV-infected individuals cycling between on and off ART states.

**19**  
states



# How did we capture the force of HIV infection?



Assortative sexual mixing imposed: HIV-infected and uninfected individuals had a higher probability of mixing within the same race/ethnic groups, informed by literature estimates for MSM<sup>9</sup>, and Southern regional estimates derived from the National Survey of Family Growth for Heterosexuals<sup>10</sup>.

# Our evidence synthesis, at a glance

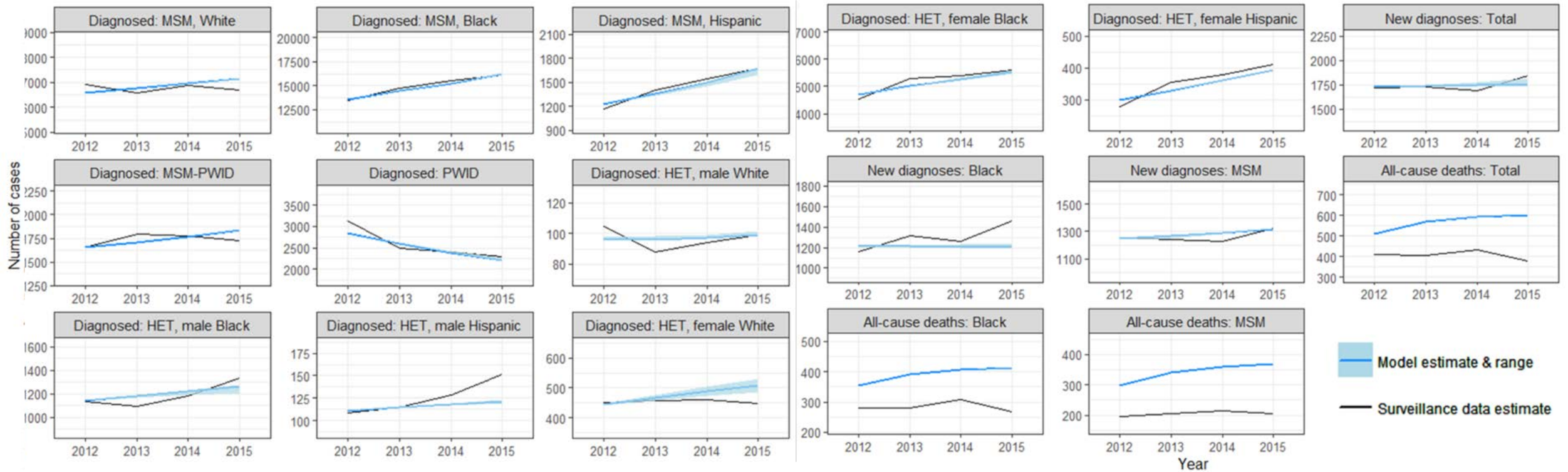
- We identified data points that required city-specific data and stratification by gender, risk group and race/ethnicity a priori and sought out databases for primary analysis to augment our evidence synthesis.
- We collected data from 2012 to 2015, with 2017 PrEP data included, given the steep increases in its uptake.
- We ranked the quality of each parameter using ***context- and domain-specific*** criteria.
- We synthesized evidence from:
  - 57 peer-reviewed publications
  - 23 public health and surveillance reports
  - Primary analyses of 11 data sets

# Our evidence synthesis, at a glance

Model parameter category	Description of parameters	Number of common parameters	Best- or moderate-quality (%)	Number of city-specific parameters	Best- or moderate-quality (%)						Total by category
					ATL	BAL	LA	MIA	NYC	SEA	
<b>1. Initial population estimates and population dynamics</b>											
1.1 Risk-stratified population estimates	Total population	0	--	18	100%	83%	100%	100%	100%	100%	18
1.2 Number of PLHIV	PLHIV population infected/unaware, diagnosed, and on-ART	84	0%	558	71%	74%	74%	71%	74%	74%	642
1.3 Population dynamics	Population entry/maturation rates, mortality rates and migration rates	0	--	372	26%	26%	26%	26%	26%	26%	372
1.4 HIV-negative population	HIV-negative population with proportion who were screened	0	--	42	14%	14%	14%	14%	43%	14%	42
<b>2. Parameters used to calculate the probability of HIV transmission</b>											
2.1 Sexual risk behaviors	Proportion of high/low sexual risk, number of same and opposite sex sexual partners, reduction in sexual partners due to diagnosis	1	100%	156	19%	8%	19%	19%	19%	19%	157
2.2 Injection risk behaviors	Number of injections, proportion of shared injections	1	100%	10	90%	0%	90%	90%	90%	90%	11
2.3 Sexual mixing patterns	Asortativity for heterosexual, MSM, and injection	0	--	12	0%	0%	0%	0%	0%	0%	12
2.4 Probability of transmission	Probability of transmission through sexual contact and injection, reduced transmission due to ART, and condom effectiveness	21	100%	0	--	--	--	--	--	--	21
<b>3. Screening, diagnosis, treatment and HIV disease progression</b>											
3.1 HIV testing	Rates of HIV testing, increased testing for high-risk, and symptom-based case finding rate	2	0%	42	14%	14%	14%	14%	43%	14%	44
3.2 ART initiation	ART initiation proportion at diagnosis and ART initiation rate for PLHIV who do not immediately initiate ART	0	--	84	100%	100%	100%	100%	100%	100%	84
3.3 ART retention and re-initiation	Rates of ART retention and ART re-initiation post-dropout	0	--	72	100%	100%	100%	100%	100%	100%	72
3.4 HIV disease progression on ART	Disease progression for diagnosed (on ART)	0	--	108	100%	100%	100%	100%	100%	100%	108
3.5 HIV disease progression off ART	Disease progression for diagnosed (off ART), infected/unaware, and acute to chronic HIV for infected and diagnosed	4	100%	0	--	--	--	--	--	--	4
<b>4. HIV prevention programs</b>											
4.1 Syringe service programs coverage	Total syringe distribution volume	0	--	1	0%	100%	100%	0%	100%	100%	1
4.2 Opioid agonist treatment (OAT)	Number of PWID/MWID receiving OAT, OAT entry/dropout rates, OAT effectiveness on ART adherence and reduction of shared injections	3	100%	9	0%	100%	100%	100%	100%	100%	12
4.3 Pre-exposure prophylaxis (PrEP)	PrEP uptake; PrEP effect on testing and risk of infection	3	33%	7	100%	0%	100%	100%	100%	100%	10
<b>5. Costs of medical care</b>											
5.1 HIV-infected	Costs of medical care among PLHIV	0	--	24	0%	100%	100%	0%	100%	100%	24
5.2 HIV-negative	Costs of medical care for HIV-negative individuals; multiplier for PWID	0	--	2	0%	100%	100%	100%	100%	100%	2
<b>6. Health utility weights</b>											
6.1 HIV-infected	Health utility weights for infected, diagnosed, on-ART by HIV disease severity; multipliers for PWID and OAT	27	100%	0	--	--	--	--	--	--	27
6.2 HIV-negative	Reference health state for HIV-infected; multipliers for PWID and OAT	3	0%	0	--	--	--	--	--	--	3
<b>Total</b>		<b>150</b>	<b>39%</b>	<b>1517</b>	<b>56%</b>	<b>56%</b>	<b>58%</b>	<b>57%</b>	<b>60%</b>	<b>58%</b>	<b>1667</b>

# How did we 'calibrate' the model?

Zang et al, Med Decis Making. 2020;40(1):3-16.

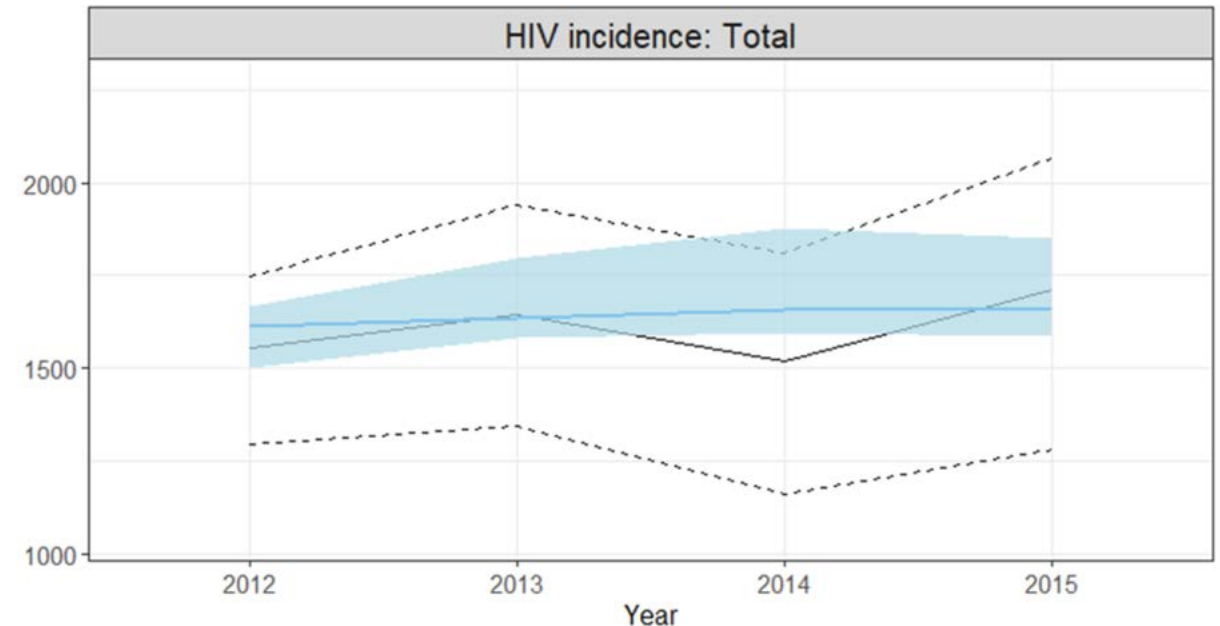
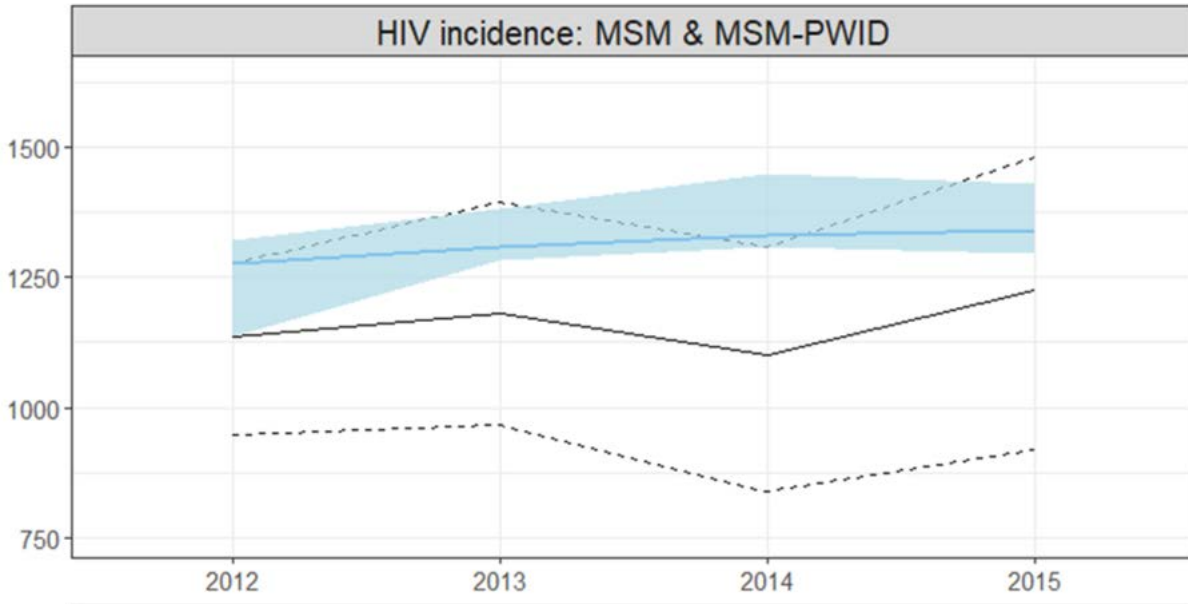


**Model calibration:** adjusting the values of the most uncertain data points to establish ranges that produce outputs that best match surveillance data

- We identified 17 calibration targets between 2012-2015
- New/total diagnoses, by risk and ethnic group; mortality by risk and ethnic group

# How did we 'validate' the model?

Zang et al, Med Decis Making. 2020;40(1):3-16.



Model estimate & range

Surveillance data estimate & range

**Model validation:** the process of evaluating a model's accuracy in making relevant projections

- In 2,000 simulations, the estimated incidence fell within the externally-estimated range 81% of the time.
- The ranges for external estimates were constructed using estimated ranges of Georgia incidence estimates, given the lack of Atlanta EMA estimates.

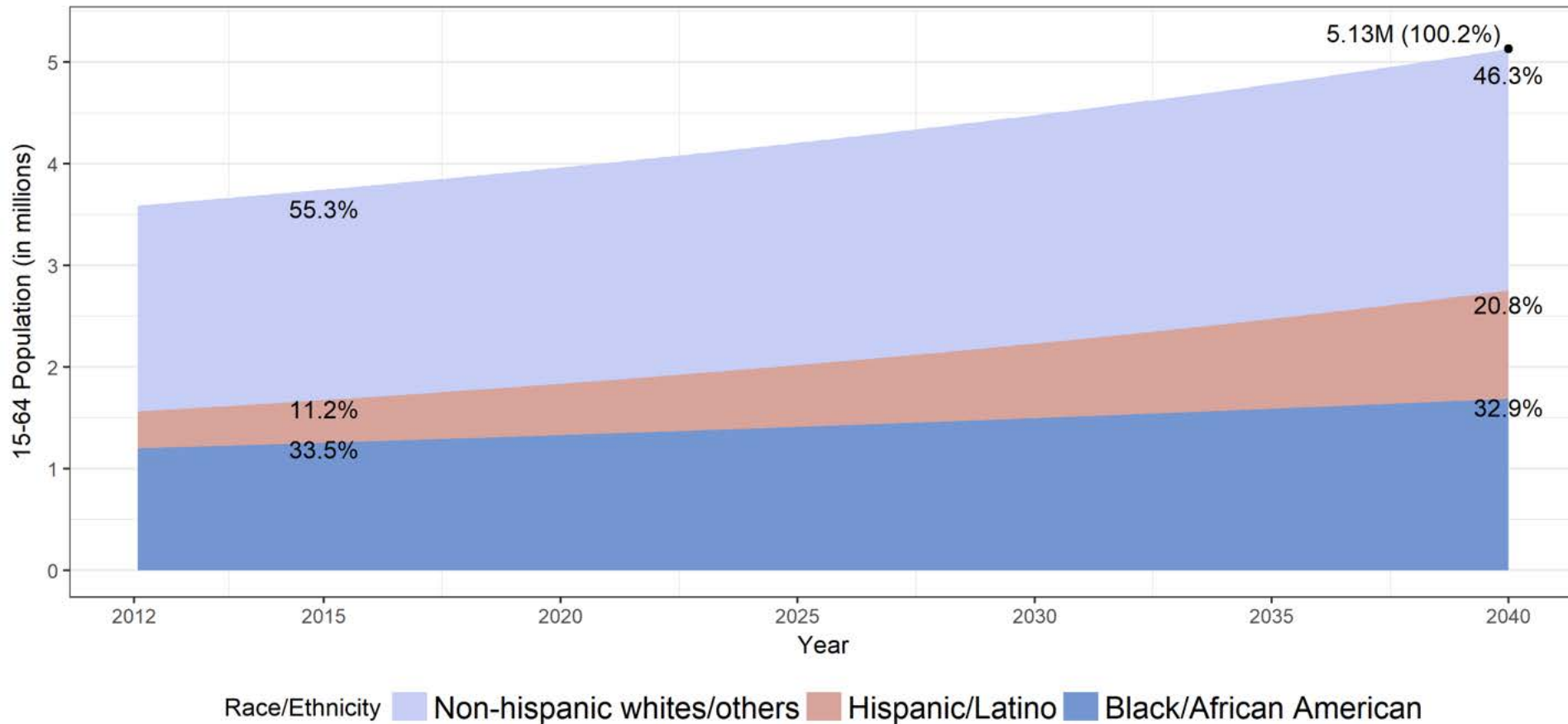


# Defining the ‘status quo’, for sake of comparison

- We need to establish a “comparator” scenario to serve as the basis of comparison for ALL combination implementation scenarios for a given city
- This reference case is necessarily built using historical data, and holding constant aspects of the HIV microepidemic according to the **latest available evidence**
- **We’ve...**
  - Matched official population projections (adults aged 15-64), by ethnicity
  - Maintained the HIV testing rate, and the percentage of PLHIV on ART, accessing OAT and PrEP
  - Maintained the percentage of people we defined as ‘high risk’
  - Accounted for aging by adjusting death and maturation rates

# Atlanta's projected population, demographic shift

Model population (ATL) by race/ethnicity, with total compared to projected population (%)



- According to the Atlanta Regional Commission<sup>1</sup>, Atlanta's adult population (15-64) is projected to grow to 5.13 million in 2040.
- The Hispanic population is expected to nearly double in proportion during that time (11.2% to 20.8%).

# Selected Evidence-Based Interventions

Selected from the CDC's Compendium of Evidence-Based Interventions and Best Practices for HIV Prevention

## Protect

- Syringe services program (SSP)
- Medication for opioid use disorder (MOUD) with buprenorphine
- MOUD with methadone
- Targeted pre-exposure prophylaxis (PrEP) for high-risk MSM & MWID



## Diagnose

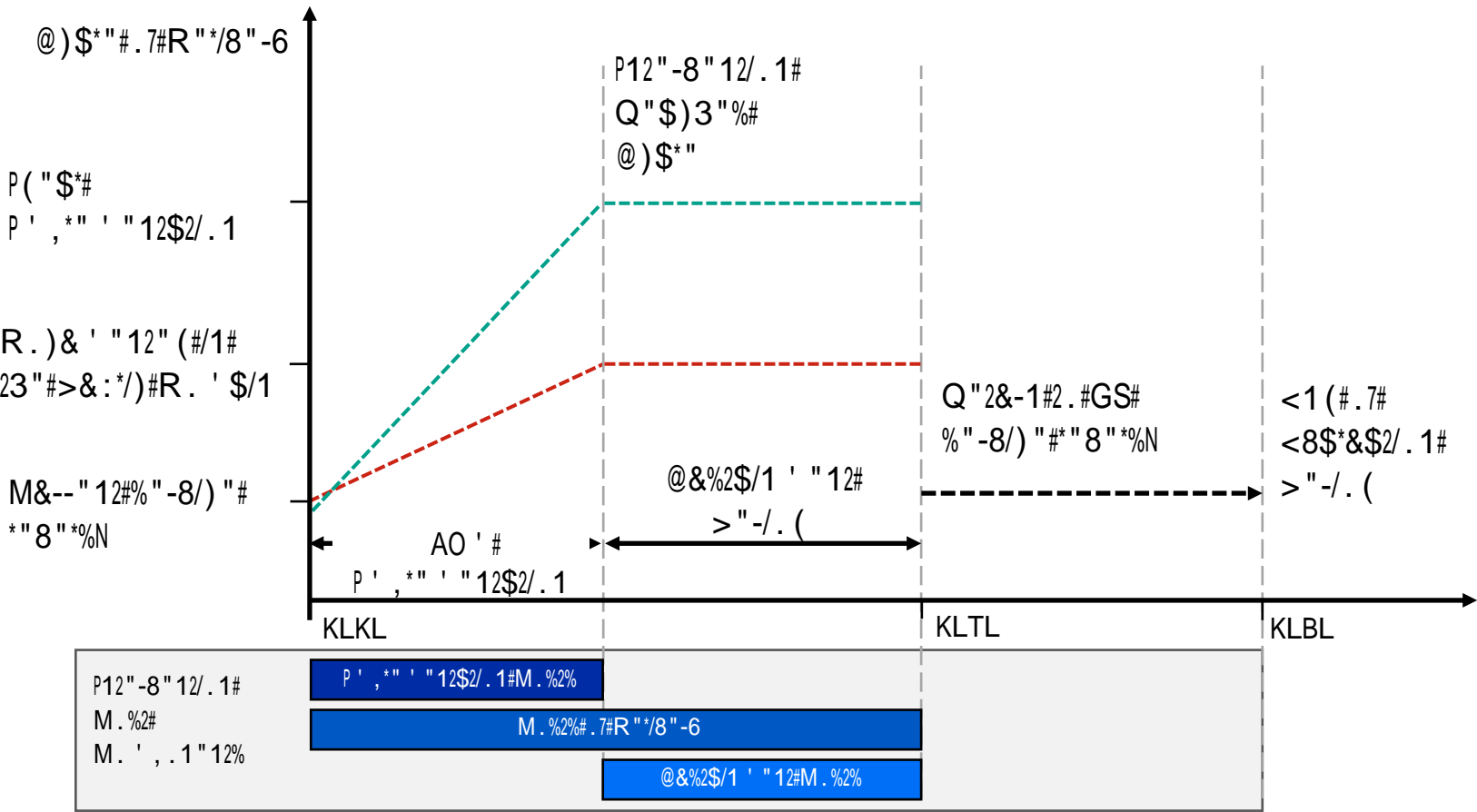
- Opt-out testing in ER
- Opt-out testing in primary care (PC)
- EMR testing offer reminder
- Nurse-initiated rapid testing
- MOUD integrated rapid testing



## Treat

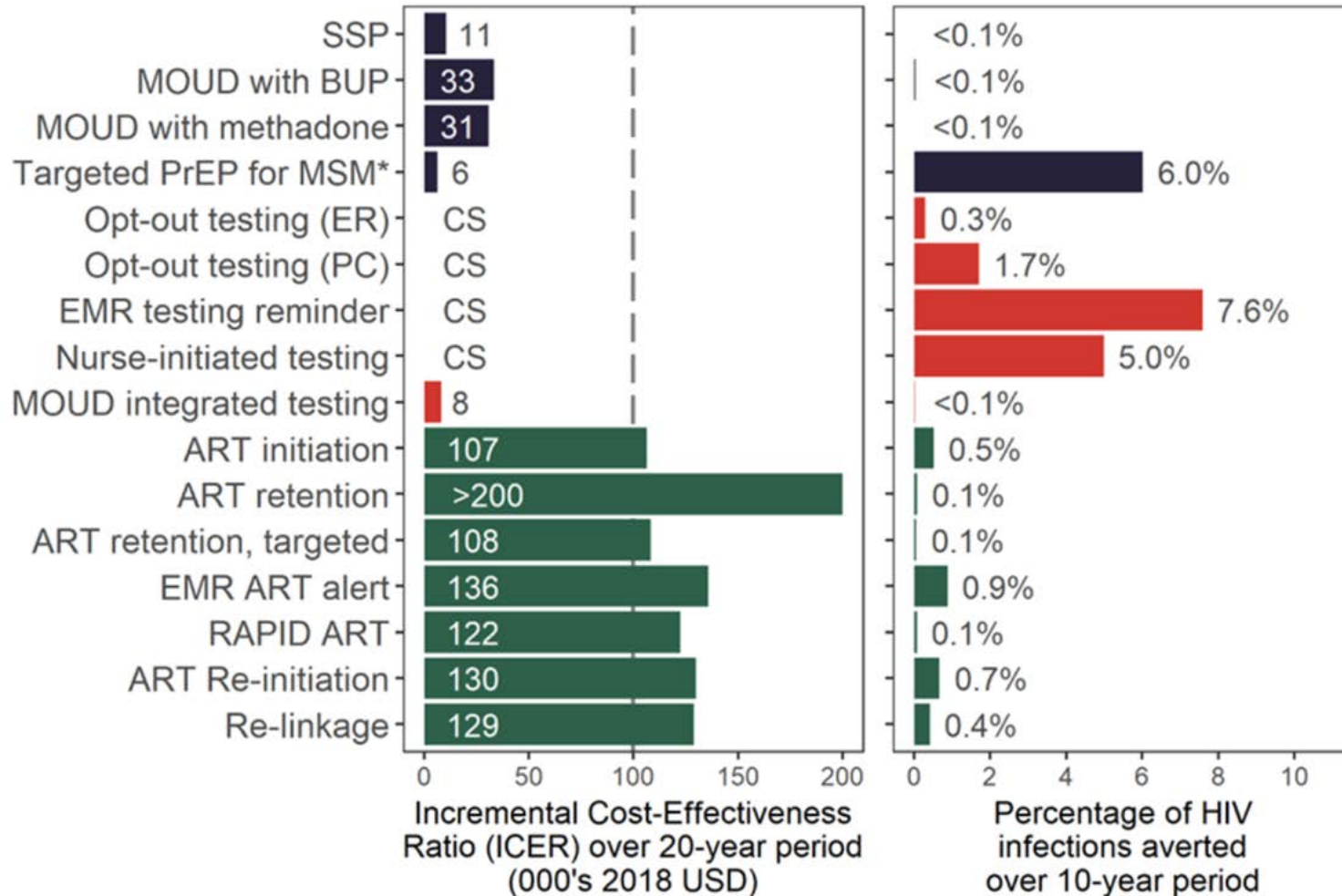
- Case management for initiation
- Care coordination for retention
- Care coordination for retention, targeted
- EMR alert of suboptimal ART
- Same-day ART initiation
  
- Enhanced personal contact
- Re-linkage program

! " # \$ % & % \$ # ' \$ & ( ) \* ' ( ' + , \$ - + % \$ ' . , & ( - , ' \$ / " . , - \$ 0 " 1 \$  
 ' 2 & % ' + / ' 3 4 - . ' % \$ & + , ' 1 2 ' + , & " + . \$ & + \$ " 5 1 \$ ( " % ' \* 6



! " # \$ % & ' " ( # ! " # ! " # \$ % # & ' ( % ) \$ \* " +  
 & , # \$ ) - . % % # - / % 0 # \$ 1 ( # " 2 3 1 / ) # 4 - . & , % #  
 5 / ' , \* 6 / 1 4 # 3 / 4 3 " - # % ) \$ \* " # . 7 #  
 ( " \* / 8 " - 6 # 7 . \* . 9 / 1 4 # / ' , \* " ' " 1 2 \$ 2 / . 1 #  
 7 . - # 4 - . & , % # - " ) " / 8 / 1 4 # 4 - " \$ 2 " - #  
 : \$ % " \* / 1 " # % " - 8 / ) " # \* " 8 " \* % ;  
 < 4 = # > - < > ) . 8 " - \$ 4 " # 7 . - # 3 / 4 3 + - / % 0 #  
 ? @ ? # 9 \$ % # A B C # D ! 3 / 2 " E = # F C #  
 D G \* \$ ) O E # \$ 1 ( # H C # D I / % , \$ 1 / ) E J # 9 " #  
 \$ % % & ' " ( # 1 " 9 \* 6 " # 1 4 \$ 4 / 1 4 # ? @ ? #  
 9 / \* # : " # / 1 # 2 3 " % " # ) ' \* + , ! " # ! " # \$ % # & )  
 9 / 2 3 . & 2 # \$ ( ( / 2 . 1 \$ \* # " 7 7 . - 2 % # - " ( & ) " #  
 ( / % , \$ - / 2 / " % # / 1 # \$ ) ) " % % ;

# What can be achieved with individual evidence-based interventions at scales of delivery documented in the public domain?



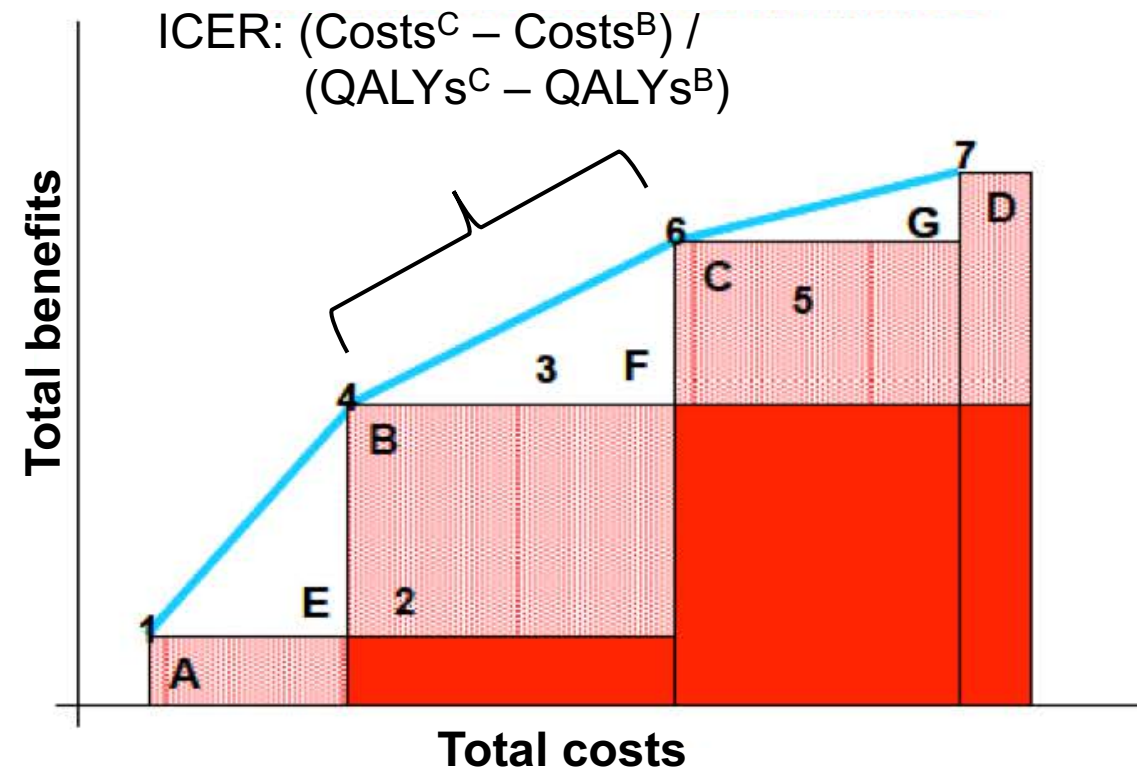
- The costs of interventions to **Diagnose** HIV infections would be more than offset by cost savings resulting from delayed morbidity and mortality via early detection, and reductions in HIV incidence over a twenty-year time horizon.

- Among interventions to **Treat** HIV/AIDS, none were cost-effective at conventional levels.

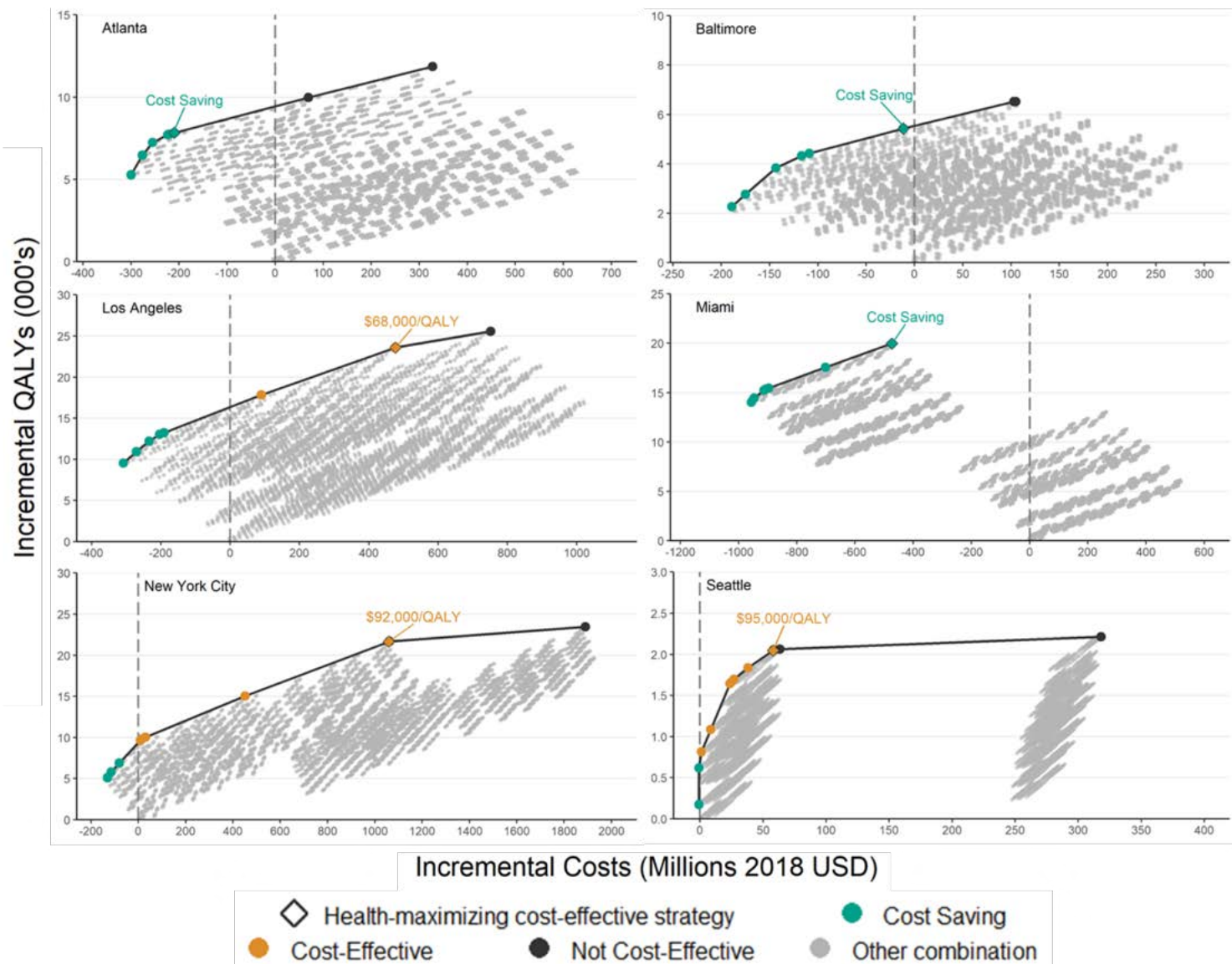
- No single intervention will reduce HIV incidence by more than 7.6% between 2020 and 2030.

# How we determined the highest-valued combination implementation strategies

- The health production function: the maximum health benefits that can be produced out of a given combination of inputs.
- The set of points corresponding to combination implementation strategies providing the greatest health benefits at different investment levels.
- Incremental Cost Effectiveness Ratios (ICERs) for combinations of strategies lying along the health production function are compared to the **next-most resource intensive strategy**
- We chose the strategy that produced the maximum health benefits while still remaining cost-effective (ICER < \$100,000/QALY)
- “health care sector” perspective: included all government, employer-paid and out-of-pocket healthcare expenditures.



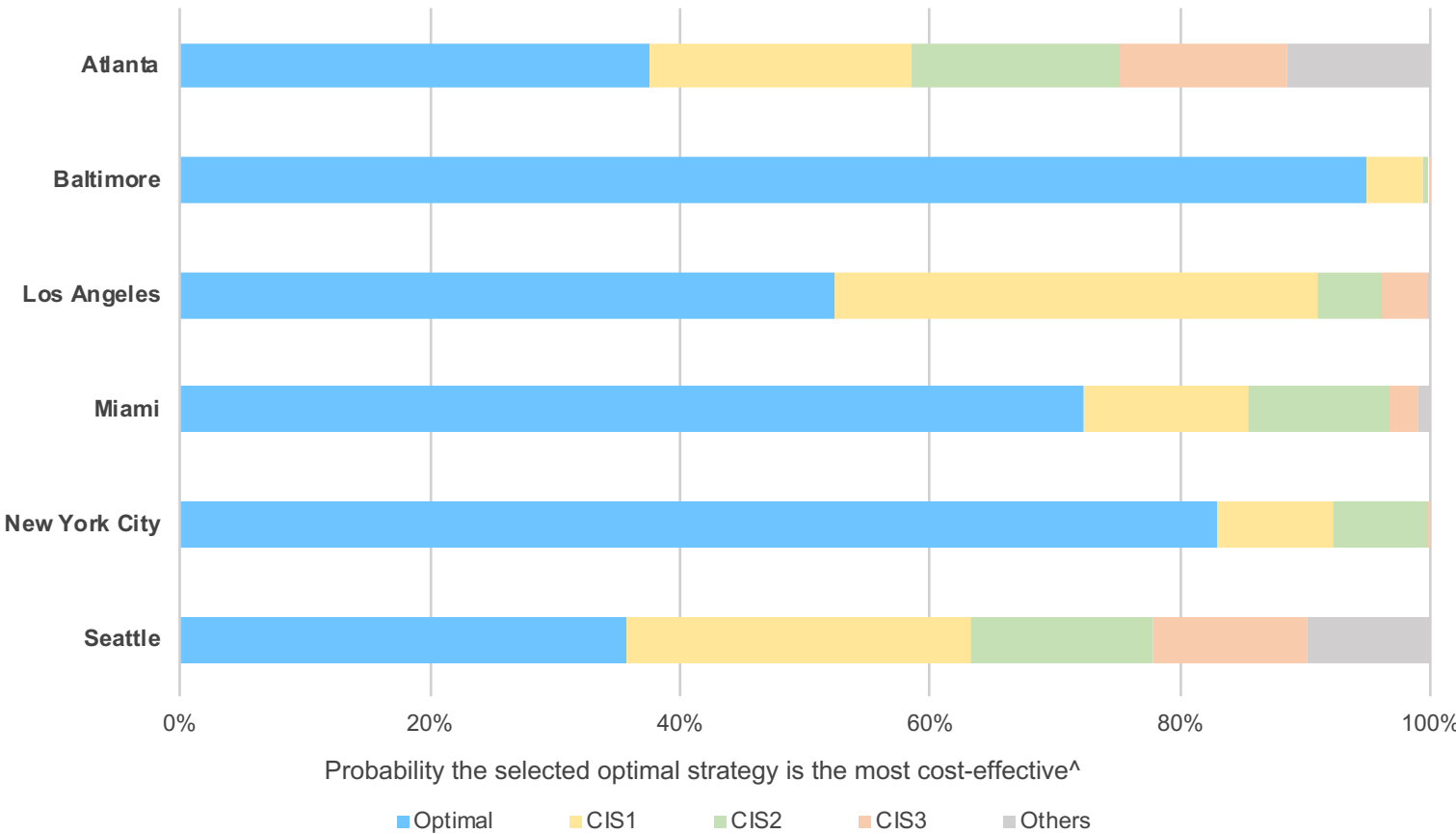
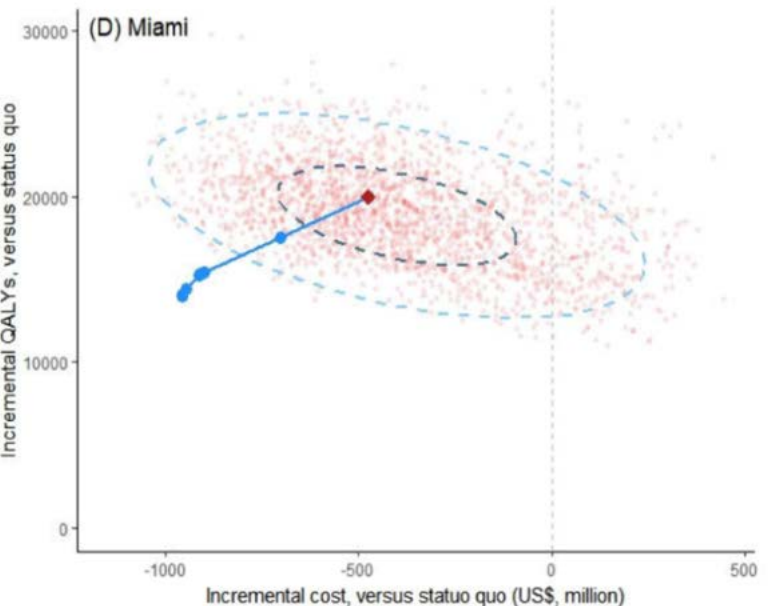
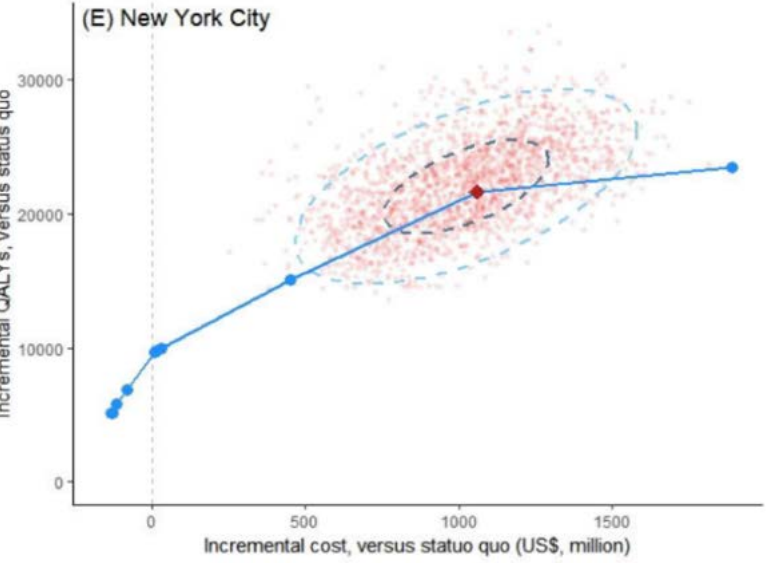
# Highest-valued combination implementation strategies across cities



- Each city's health-maximizing combination implementation strategy was unique; between 9 and 13 individual evidence-based interventions included
- Health impacts and associated costs differed substantially across cities
- Greatest value in intervening in cities with greatest need

# How certain are we in our recommendations?

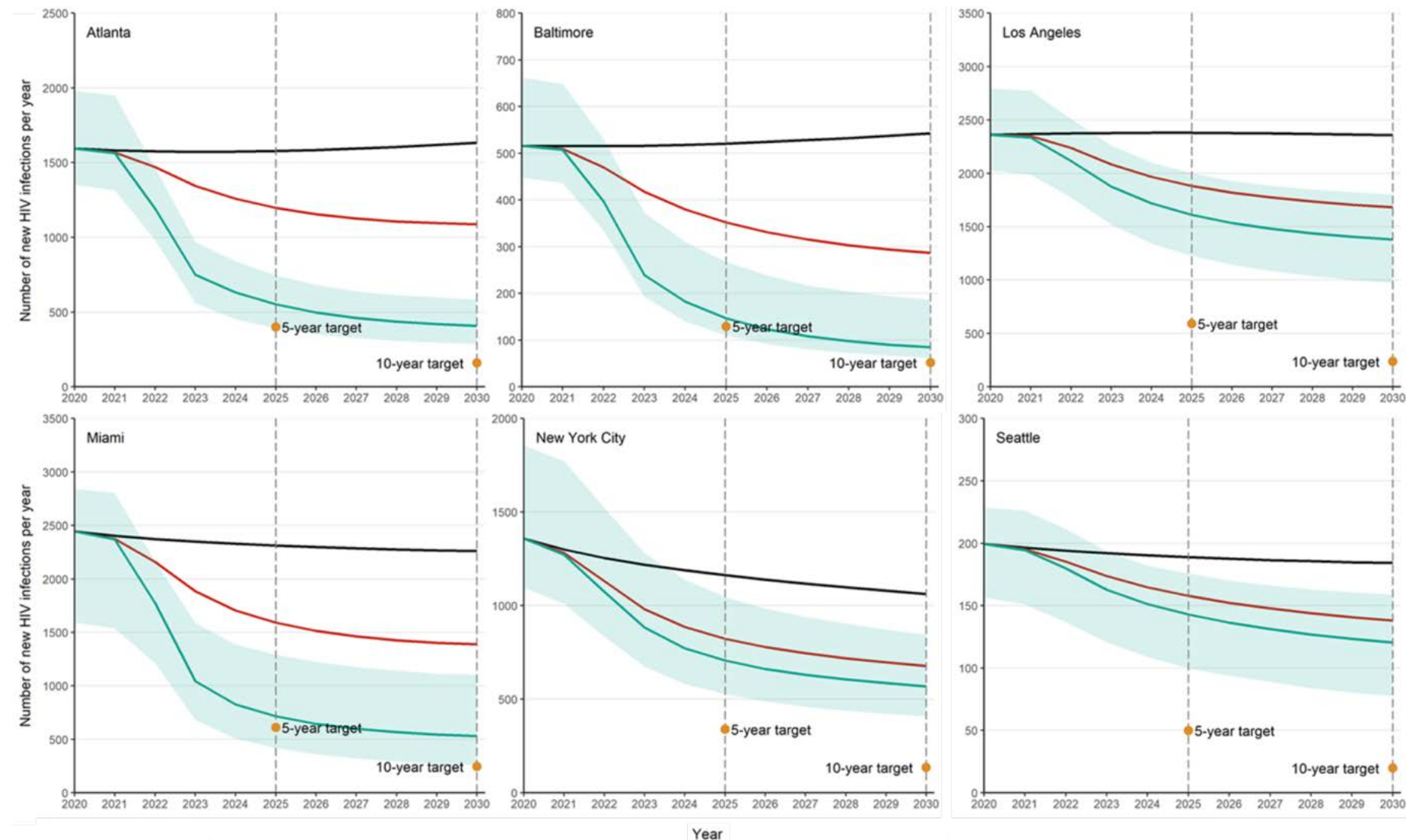
Zang et al. Med Decis Making. In press.



The selected strategies had a high probability of providing the greatest health gains compared to the most proximal competing strategies, with probabilities ranging from 35.7% (Seattle) to 94.9% (Baltimore).



# Estimated impact on HIV incidence: 2020-2030

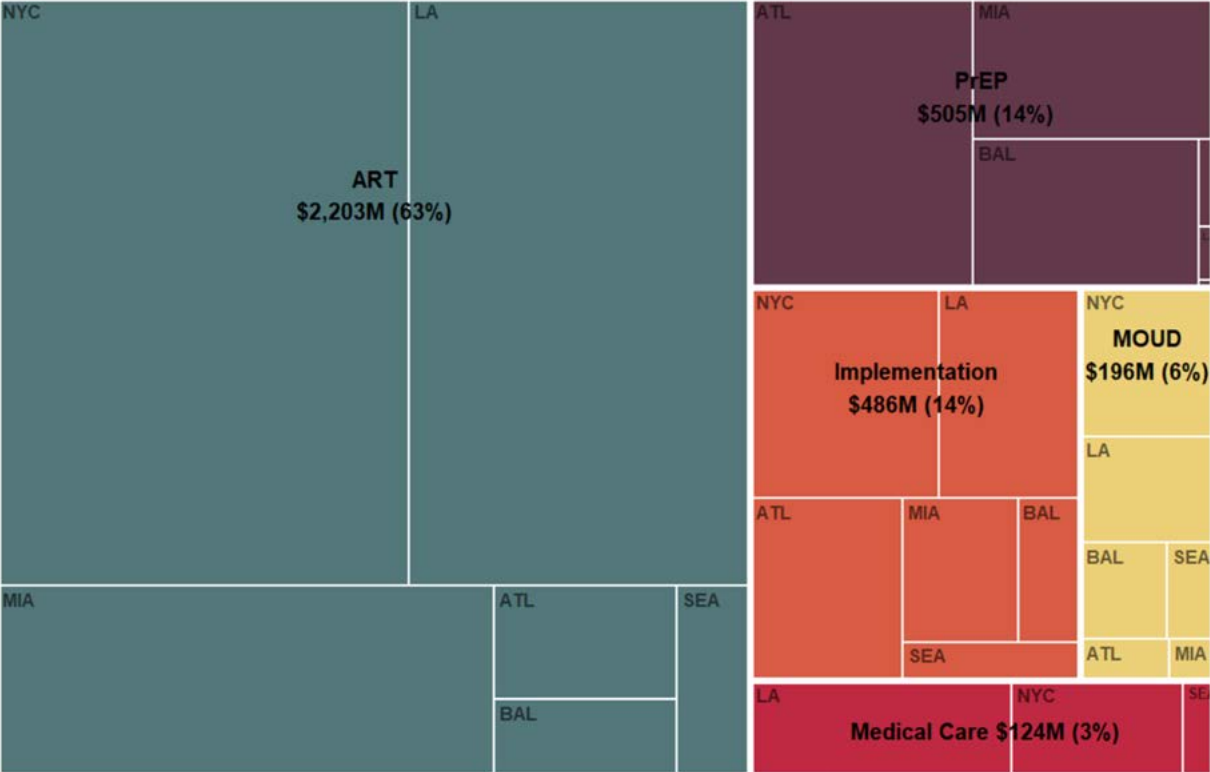


— Status Quo — Previously-documented Scale — Ideal Implementation

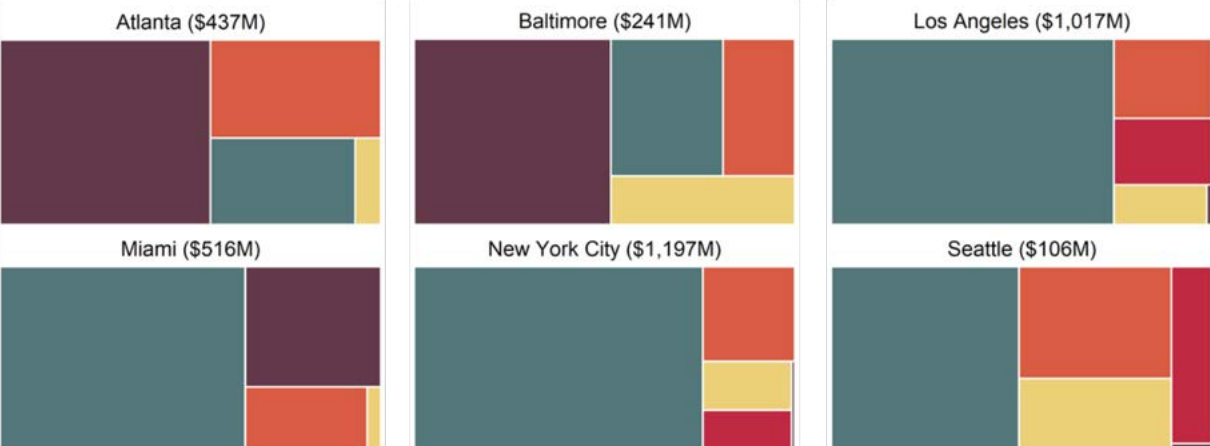
- **Previously-documented scale:** incidence reductions of 30.7% (19.1%-43.7%) in Seattle to 50.1% (41.5%-58.0%) in NYC by 2030

- **Ideal Implementation:** approaching EHE targets in Atlanta, Baltimore and Miami; LA, NYC and Seattle reaching 60.7%, 58.1% and 39.5% reductions.

# Estimated expenditures to implement optimal strategies at previously-documented scale: 2020-2030



- **Strategies implemented at previously-documented scale-up:** estimated cost of \$4.45B in present-value by 2030.
- Investment would be front-loaded, peaking at an annual expenditure of \$559M in 2024.
- Implementing these strategies for our focal cities would require 1.9 times the proposed US national budget allotment for 2020 to the ‘Ending the HIV Epidemic’ initiative.



# Limitations

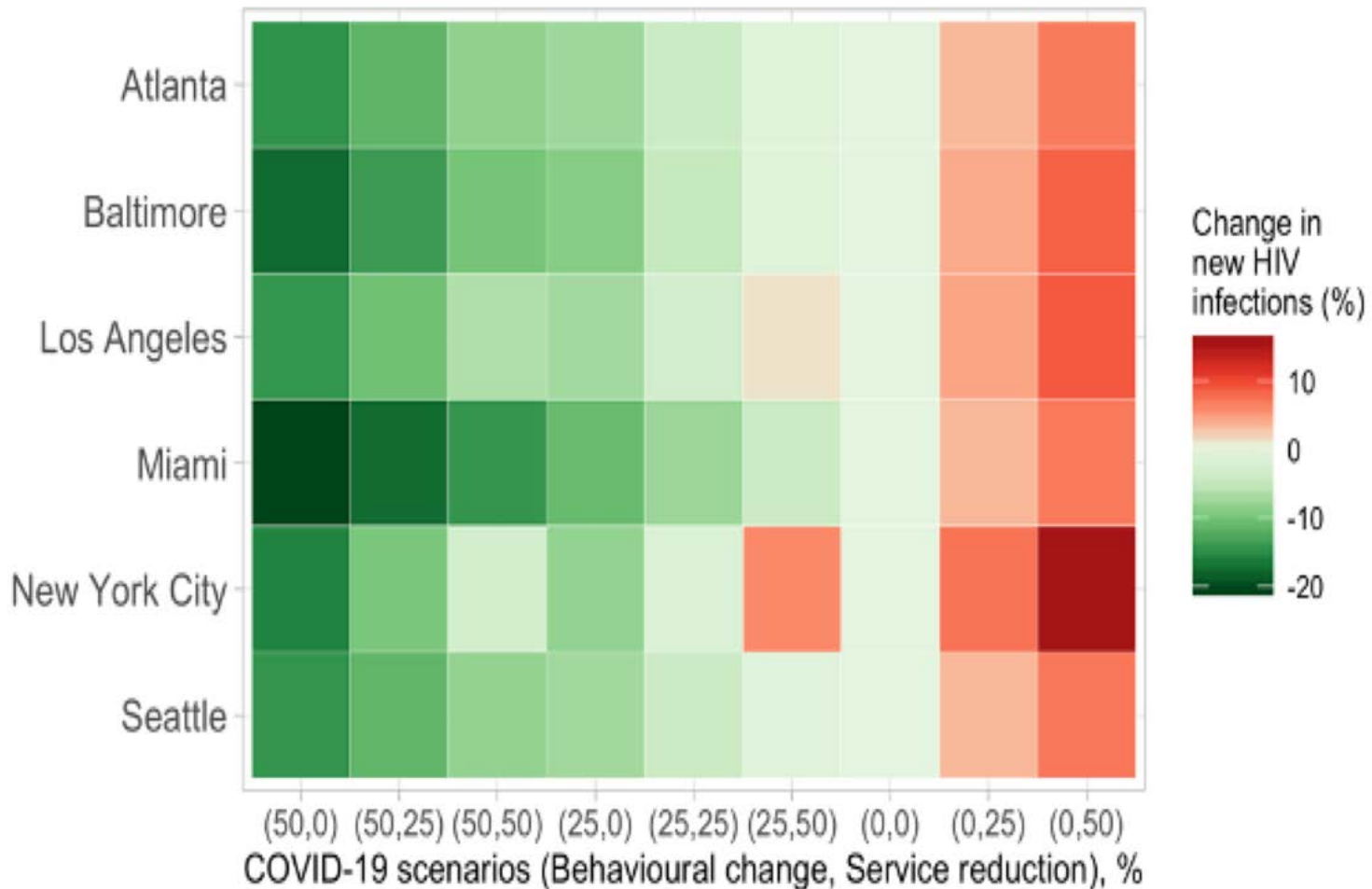
- Simplifying assumptions in the structure of the model, transmission
- Limits in the evidence base on which it was built, including most recently-released data
- Interventions we assessed are not exhaustive: potential effects of ***Respond*** strategies to be determined
- Uncertainty on the potential scale of delivery, and the attributable costs of implementation, delivery and sustainment of each intervention within local contexts

# Conclusions

- There is considerable value in implementing a range of evidence-based interventions for HIV/AIDS BUT they need to be **implemented in combination** to approach EHE goals
- Current funding commitments will fall short of reaching EHE targets
- The EHE goals are not attainable without large reductions in new infections among black and Hispanic MSM in particular
  - At ideal implementation, incidence in 2030 among black and Hispanic MSM in Miami would be reduced by 78.8% and 84.7%, nearly eliminating disparities relative to white MSM
- We only considered costs of delivering interventions directly impacting HIV-related outcomes
  - The limited scale-up of delivery for interventions reflects limits on access to care.
- Interventions will need to be augmented with efforts to:
  - reduce stigma
  - improve health literacy
  - address capacity constraints in healthcare delivery
  - reduce other social and structural barriers to healthcare access

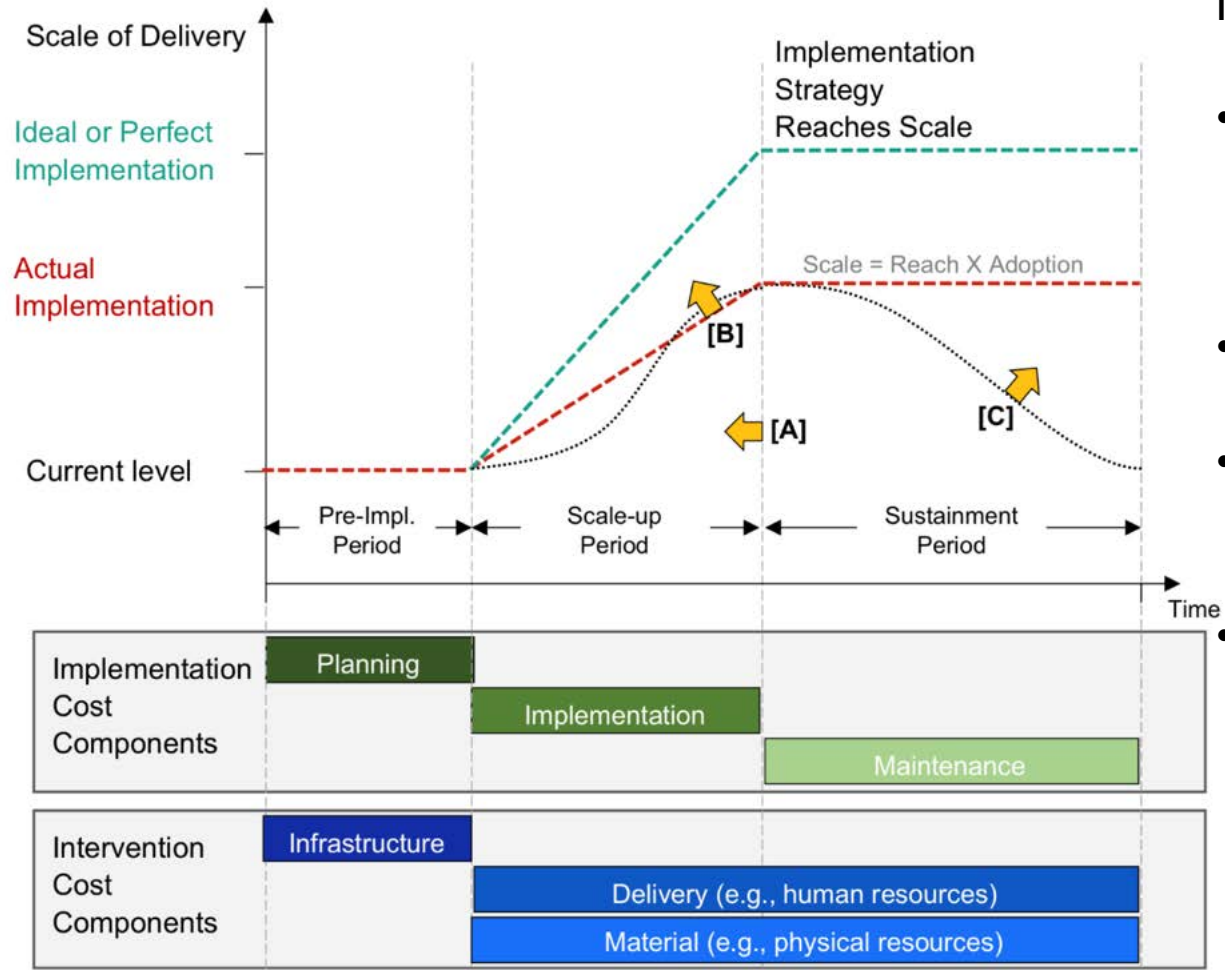
# Modeling the epidemiological impact of COVID-19 on HIV

- What if we offered linked, opt-out HIV testing alongside SARS-CoV-2 testing and contact tracing accounting a range of effects of COVID-19 on risk behaviors and interruptions to HIV health service provision?



- Compared to holding service levels constant, the addition of linked opt out HIV testing offered to 90% of the adult population could avert **9.1%** of infections over 5 years (under the 'best-case' scenario of 50% reductions in sexual and drug injection risk behavior and no disruptions to health service provision due to COVID-19)
- The intervention would be cost-saving over a 20-year time horizon

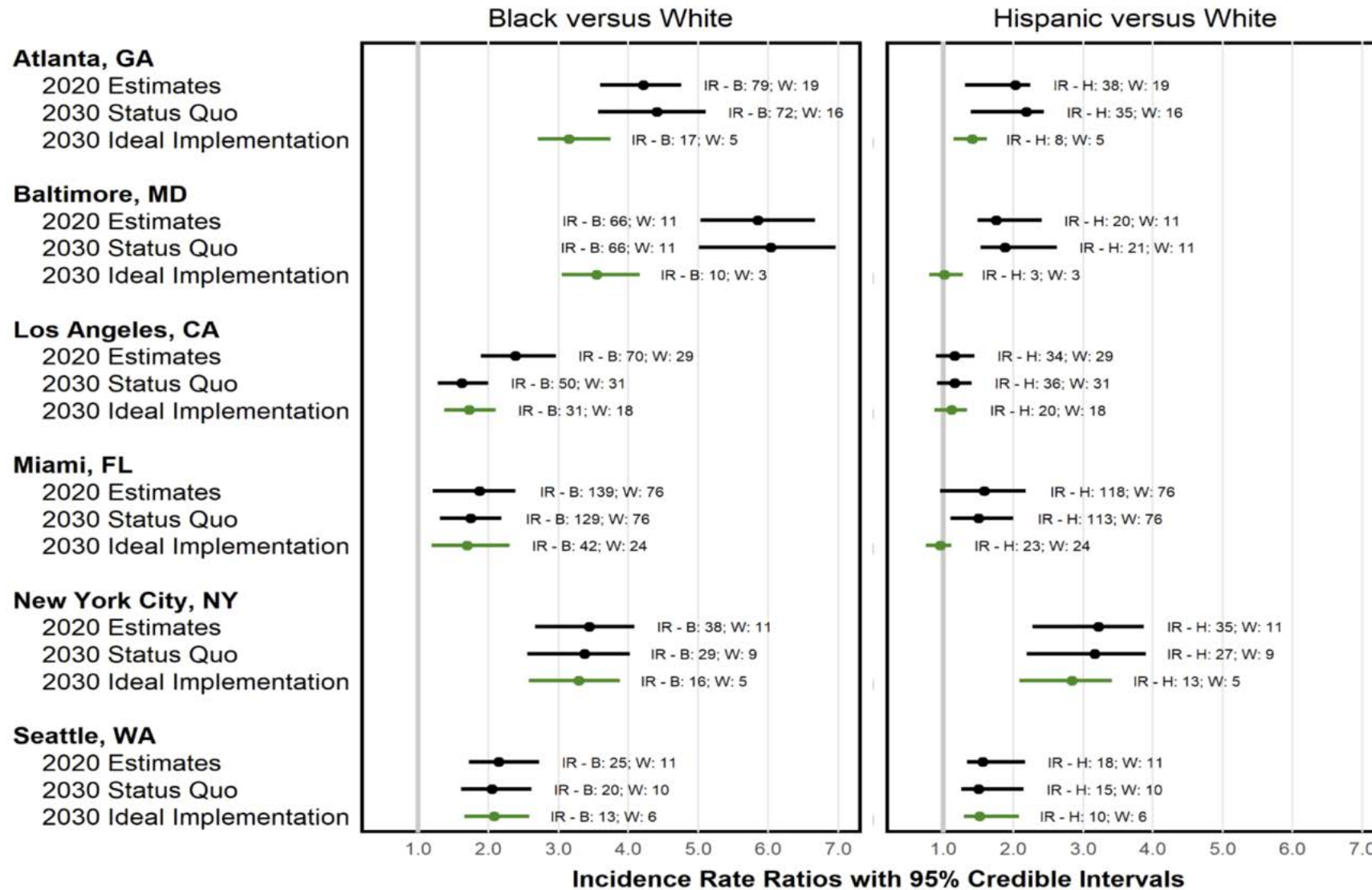
# Integrating IS Principles in Health Economic Modeling



Model-based CEA can advance IS:

- Can create an in silico environment to assess interventions at different scale, adoption and sustainment, within different local contexts
- Estimate the 'value of perfect implementation'
- Identify where to target limited implementation resources (A, B or C)
- Need real world data on scale, adoption, effectiveness, sustainment and costs

# 'Ending the Epidemic' will not happen without addressing racial/ethnic disparities



Even with city-specific combinations of strategies implemented at ideal levels, wide racial/ethnic disparities in HIV incidence would persist without addressing existing inequities in access to healthcare.

# What if we could focus resources on reducing racial/ethnic disparities?

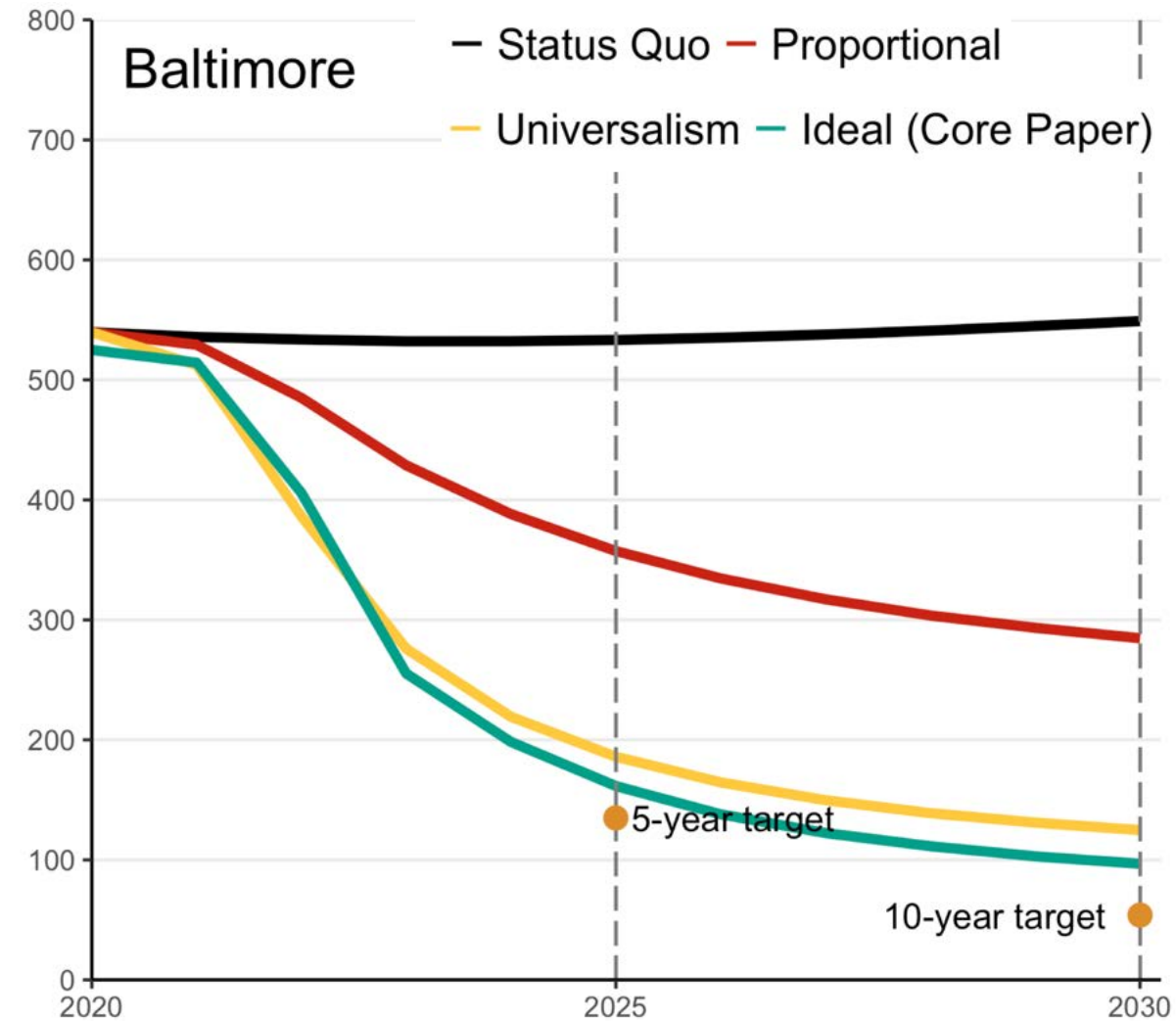
We assessed combinations of interventions using a novel methodological framework: **Distributional cost-effectiveness analysis (DCEA)**

## Two implementation scenarios:

**Proportional scale-up:** Scale-up implemented proportionally across race/ethnic groups (i.e. higher scale of delivery for groups receiving greater service levels at baseline). Expected level of scale-up within current social and structural constraints on access to care.

**Proportionate universalism:** Scale-up implemented across race/ethnic groups proportionally to their respective HIV burden (HIV incidence).

**Early results: Greater benefits, lower long-term costs under proportionate universalism for the same effort level.**





# Applying a Dissemination Scientific Perspective




Editorial



*Medical Decision Making*  
2020, Vol. 40(6) 718–721  
© The Author(s) 2020  
Article reuse guidelines:  
sagepub.com/journals-permissions  
DOI: 10.1177/0272989X20945308  
journals.sagepub.com/home/mdm



## Dissemination Science to Advance the Use of Simulation Modeling: Our Obligation Moving Forward

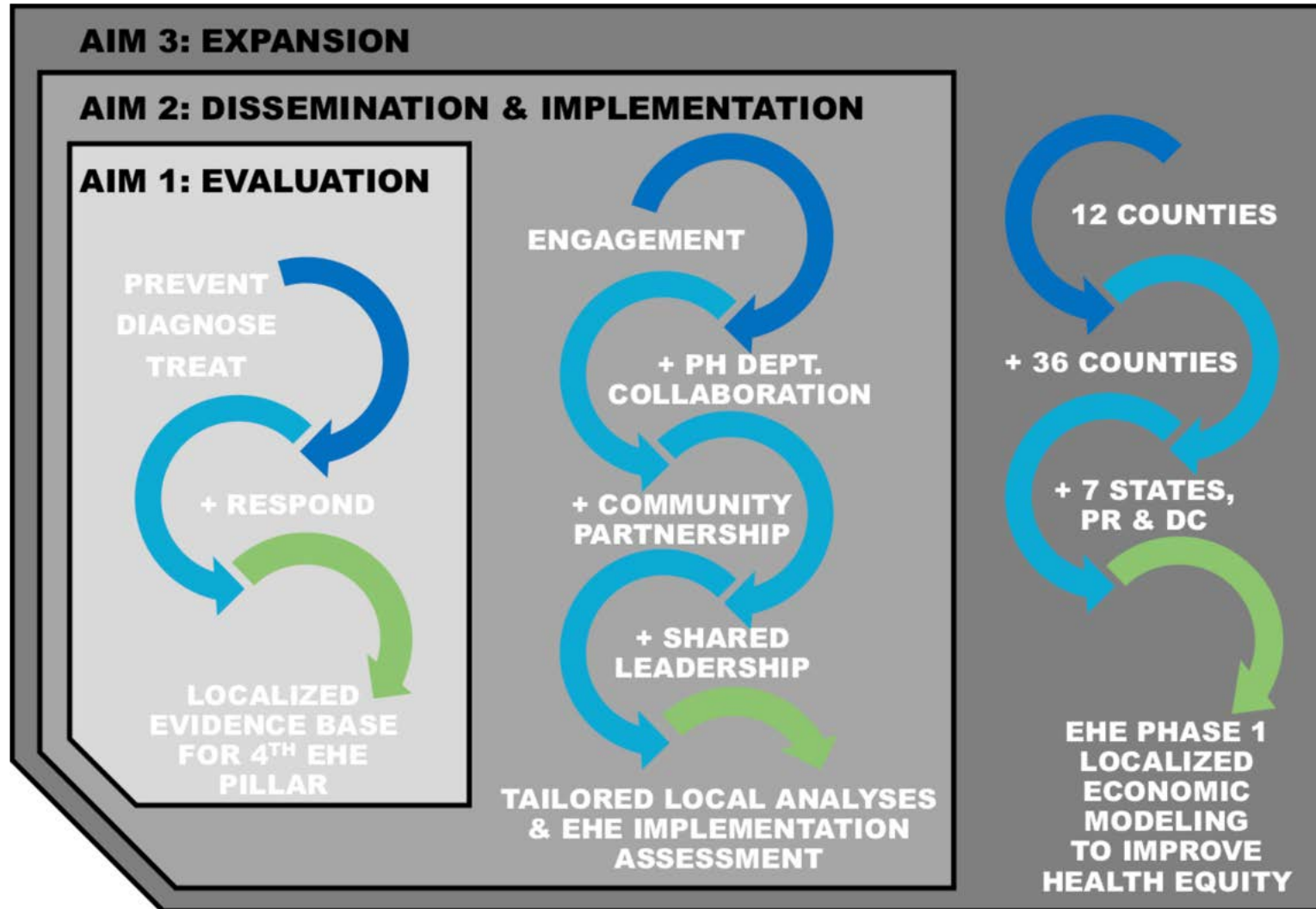
Bohdan Nosyk , Janet Weiner, Emanuel Krebs, Xiao Zang, Benjamin Enns, Czarina N. Behrends, Daniel J. Feaster, Hawre Jalal , Brandon D. L. Marshall, Ankur Pandya, Bruce R. Schackman , and Zachary F. Meisel

Date received: June 15, 2020; accepted: July 7, 2020

Our model code on Github: <https://HERU-LEM.github.io/LEMHIVpack/>

Our team's experience in developing, translating, and disseminating the results of a simulation model for policy decisions in human immunodeficiency virus (HIV) prevention and treatment has been instructive (and humbling). In an effort to set a new standard for transparency, we published separate articles on the evidence synthesis,<sup>3</sup> calibration and validation,<sup>4</sup> baseline projections,<sup>5</sup> cost-effectiveness of individual interventions,<sup>6</sup> and, finally, our cost-effectiveness analysis of different strategies to combat HIV/AIDS in disparate geographic regions.<sup>7</sup> We followed these efforts with a closer examination of the uncertainty in our findings and the value of collecting more information to reduce this uncertainty.<sup>8</sup> Altogether, this effort took >55,000 words, 154 tables, and 45 figures to communicate (with 59%, 93%, and 60% of these respectively buried in appendices). And

# Extending our work: Our next objectives



# Acknowledgements

- The BCCfE-HERU team
- Our gracious Scientific Advisory Committee
- HIVRN, the US CDC and other partners who have shared data
- The National Institutes of Health/National Institute on Drug Abuse



# The HERU-BCCfE Team involved in this work

- *Michelle Olding, PhD(c)*
- *Dimitra Panagiotoglou, PhD*
- *Linwei Wang, MSc*
- Xiao Zang, PhD
- Emanuel Krebs, MA
- Jeong Min, MSc
- Ben Enns, MA
- Micah Piske, MSc
- Charlie Zhou, PhD(c)
- Ken Peng, BSc student
- *Amanda Quan, MPH student*
- Cassandra Mah, BSc student
- *Siyuan Chen, BSc student*

# Our Scientific Advisory Committee

- **Czarina N Behrends, PhD**, Department of Healthcare Policy and Research, Weill Cornell Medical College
- **Carlos Del Rio, MD**, Hubert Department of Global Health, Emory Center for AIDS Research, Rollins School of Public Health, Emory University
- **Julia C Dombrowski, MD**, primary with Department of Medicine, Division of Allergy & Infectious Disease, adjunct in Epidemiology, University of Washington
- **Daniel J Feaster, PhD**, Center for Family Studies, Department of Epidemiology and Public Health, Leonard M. Miller School of Medicine, University of Miami
- **Kelly A Gebo, MD**, Bloomberg School of Public Health, Johns Hopkins University
- **Matthew Golden, MD**, primary with Department of Medicine, Division of Allergy & Infectious Disease, adjunct in Epidemiology, University of Washington
- **Gregory Kirk, PhD**, Bloomberg School of Public Health, Johns Hopkins University
- **Brandon DL Marshall, PhD**, Department of Epidemiology, Brown School of Public Health, Rhode Island
- **Shruti H Mehta, PhD**, Bloomberg School of Public Health, Johns Hopkins University
- **Lisa Metsch, PhD**, Department of Sociomedical Sciences, Mailman School of Public Health, Columbia University
- **Bruce R Schackman, PhD**, Department of Healthcare Policy and Research, Weill Cornell Medical College
- **Steven Shoptaw, PhD**, Centre for HIV Identification, Prevention and Treatment Services, School of Medicine, University of California Los Angeles
- **Steffanie A Strathdee, PhD**, School of Medicine, University of California San Diego

**Questions?**

**Table 4. Preliminary Evidence Synthesis on key data sources [N = 45 unique jurisdictions]\*2**

	<b>Best quality N (%)</b>	<b>Moderate quality N (%)</b>	<b>Low quality N (%)</b>
<i>Model parameters</i>			
Available PH surveillance data	15 (33%)	18 (40%)	12 (27%)
NHBS Behavioral data	13 (29%)	7 (16%)	25 (56%)
MMP Service use data	6 (13%)	21 (47%)	18 (40%)
NA-ACCORD coverage	26 (58%)	19 (42%)	0 (0%)
<i>Core service delivery data</i>			
Testing	0 (0%)	20 (44%)	25 (56%)
ART engagement	18 (40%)	5 (11%)	22 (49%)
SSP	0 (0%)	26 (58%)	19 (42%)
MOUD	0 (0%)	45 (100%)	0 (0%)
PrEP	45 (100%)	0 (0%)	0 (0%)
<i>Calibration targets</i>			
Available PH surveillance data	15 (33%)	18 (40%)	12 (27%)
Legend: PH: public health; NHBS: National Health and Behavioral Survey; MMP: NA-ACCORD; ART: Antiretroviral therapy; SSP: Syringe sharing program; MOUD: Medications for Opioid Use Disorders; PrEP: Pre-Exposure Prophylaxis. *Excludes jurisdictions already covered in the original LEM project.			

<b>Table 5. Required steps to update and extend the model to all Phase I EHE jurisdictions</b>		
<b>Task</b>	<b>Methods and Strategy</b>	<b>Resource needs*</b>
1. Updating parameters common across cities	Individual pubmed searches.	1 Analyst, 0.5m [1]
2. Submit NHBS, MMP data requests	Coordinate data request with CDC, updating required data tables previously used.	1 Analyst, 0.5m [1]
3. Submit request for NA-ACCORD database analyses	Estimate continuous-time multistate Markov model for on-ART CD4 progression, mortality, ART dropout and re-initiation.	1 Analyst, 0.5m [1]
4. Search of county/state-level surveillance data requests	Search local epidemiological reports; Coordinate with local public health departments for data requests to match model stratification.	1 Analyst, 1m [1]
5. Targeted searches for remaining model parameters	Replicate prior search strategies; Expand on potential sources to be included.	1 Analyst, 1m [1]
6. Curating jurisdiction-specific datasets to read into the model	Stratification of evidence to match model requirements; Each datapoint will be verified by a second analyst.	4 Analysts, 1m; 1 Senior analyst (0.25 FTE) [2]
7. Re-calibrating the model for each county and model validation	Replicate calibration methodology used for initial 6-city proof of concept; Assess external validity with local stakeholders.	4 Analysts, 4m; 1 Senior analyst (0.5 FTE) [3]
8. Generating health production functions for each jurisdiction	Evaluate 23,040 possible combinations of EBIs; Determine combinations providing greatest health benefits for a range of investment levels.	3 Analysts, 2m; 1 Senior analyst (0.25 FTE) [4]
9. Estimating uncertainty surrounding health-maximizing strategies	Conduct probabilistic sensitivity analysis; Determine probability health-maximizing strategies are the most cost-effective.	3 Analysts, 1m; 1 Senior analyst (0.25 FTE) [5]

\*Estimated time and resource commitment; numbers in brackets indicate tasks performed in parallel.



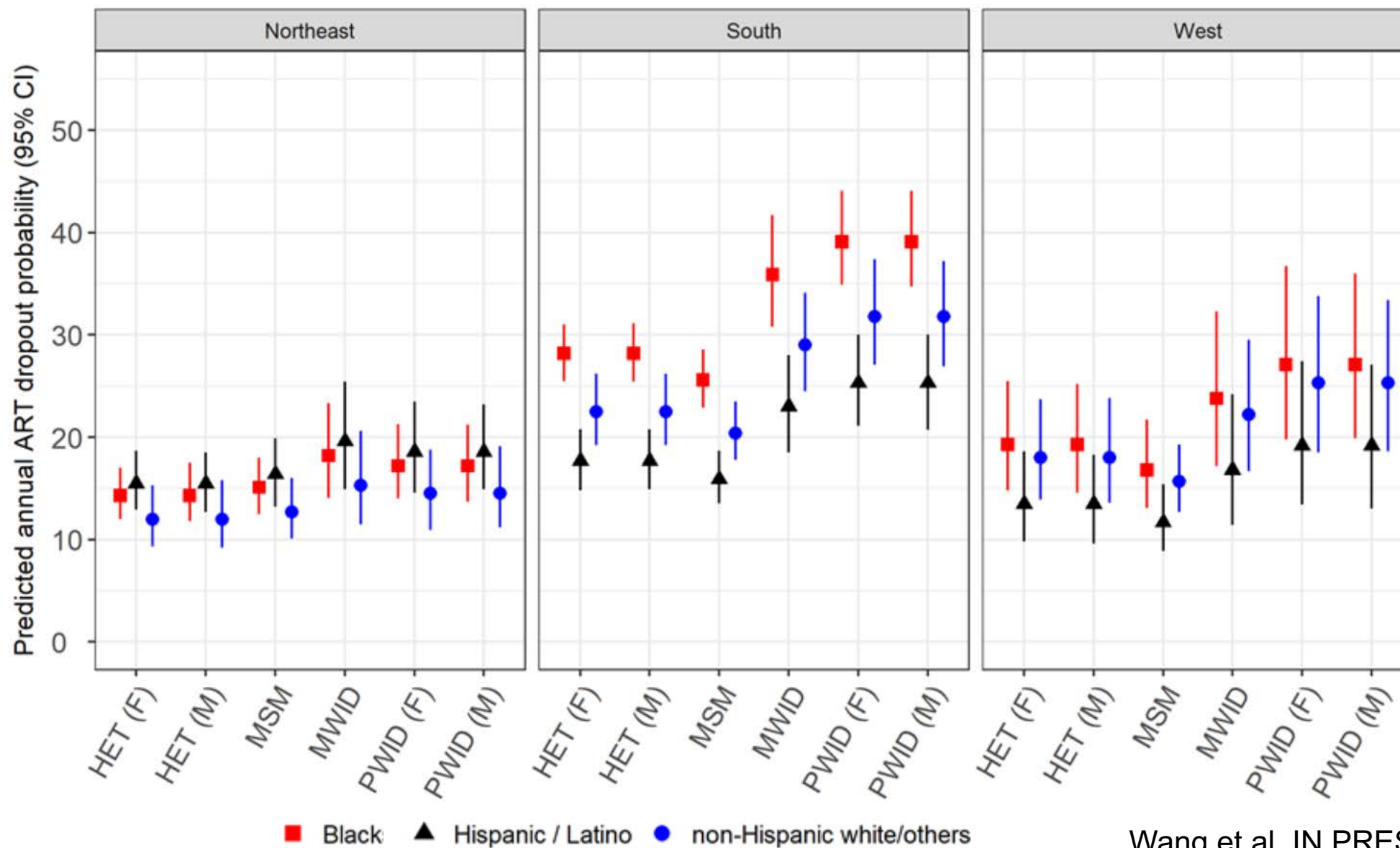


!"#\$%&' ' ' (!!\$( ) \*+&\$,"-\$&. -/012"&/,2-\$&-3. ,3)4"! -4! ,+4-#,. -5,64/06"4\$! --" (#. /

# Methods

- We calibrated and validated a dynamic compartmental transmission model to 6 US cities
- We constructed health production functions from 23,039 unique combinations of interventions to identify the optimal combination implementation strategies for a range of investment levels.
  - The strategy providing the greatest health benefits while still remaining cost-effective by conventional standards (ie.  $\leq$  \$100,000 per QALY gained) was chosen for each city
- We assessed interventions at previously-documented scales of delivery/scale-up
- We considered an 'Ideal implementation' scenario (90% target population coverage) to see how close we could get to the EtE goals

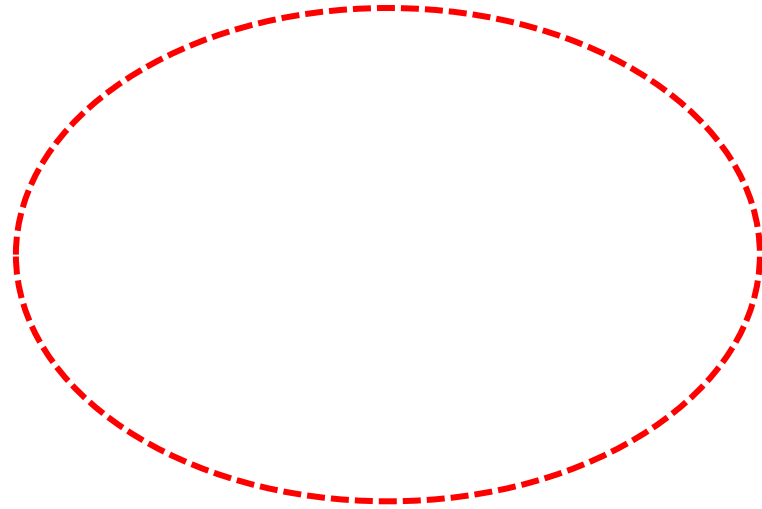
# Evidence Synthesis: Regional disparities in ART engagement



# Model calibration, validation

- We identified 17 calibration targets between 2012-2015
  - New/total diagnoses, by risk and ethnic group; mortality by risk and ethnic group
- We used the Morris Method to select the most influential free parameters for calibration.
  - Between 26-32 'free' parameters chosen for each city
- We applied the Nelder-Mead algorithm to iteratively calibrate the model to generate 2,000 best-fitting parameter sets.
- We selected HIV incidence over the calibration period (2012-2015) as the external validation target, both for the total estimates and among the MSM population.
- A majority of incidence predictions were within the uncertainty range for 5/6 cities (ranging from 21%(Miami) to 100%(NYC))

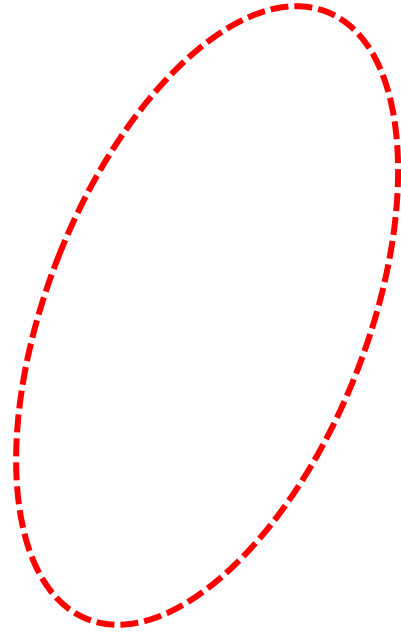
**! "#\$%&"%' ( ) \* + " , - \$ . - / % " 0 & \$ 1 ' 2 " 3 4 5 ) ( # ' - 5 6 " 7 ( 6 # ' - 5 6**



**! 8&1&#'&)"%'4\$'&9\*"#\$%&&#' (&%) (\*#+#  
,+% - # ./#012134#56789#+:#++  
9+)%- ,9#./#;<34=3>#%-#?\*(9(-:#  
)+&@(#.)(\*#+#ABCD(+\*#:%E(#  
F.\*%G.-=**

**! HF(#I.9:&%(9:#9:\*+:(,D#J&:'#  
:(9:%-,2#-.#KKL#.\*#L\*MLN#%9#  
(9:%E+:( '#:.#I.9:#+-#+' '%:.-+&#  
;11<=A>#.)(\*#AB#D(+\*9#\$F%&(#  
' (&%) (\*%- ,#.-&D#4B=0O#./#:F(#  
5678#,+% - # ./#:F(#9(&(I:( '#  
9:\*+:(,D#J40=<O#/( \$ (\*%#-/(I:%.-9#  
+)(\*:( '#%-#AB4BN=**

! "#\$%&"%' ( ) \* + " , &\$' '-&.%" / &\$-' 0 " 1 2 3 ) ( #' 4 3 5 " 6 ( 5 #' 4 3 5



! , &-&#'& )"%'2\$'&7 \*"# \$%&&#' (&%) (\*#+#  
, +%-#.#/01234#5 6789#+:#+-#  
+ ' ' %-% . -+&#% - ) (9: ; ( -:#.#/ #<=>?@ A#  
%-#B\*(9(-:#)+&C(#.) (\*#+#02DE(+\*#  
:% ; (#F.\*%G.-1#\*(9C&=%- ,#% -#+-#  
H I JK#.#/<@=13L4#B(\*#5 678#?

! MF(#9:\*+:( , E#% -N&C' %- , #O\* JO#  
, (- (\*+:( ' #+-#+' ' %:% . -+&#L4P#  
5 6789#Q=?>R# ; .\* (#% -/(N:% . -9#  
+)(\*:( ' #%-#02S2T1#UC:#+:#+-#  
%-N\*( ; (-:+&#N.9:#.#/<042?0AV#  
H I JK"#<L?=3AV 5 678# , +%- ( ' )

# Parameter inclusion for probabilistic sensitivity analysis

