2021

Cost-effectiveness of interventions targeting hard-to-reach populations living with HIV in Eastern and Southern Africa

Deo Mujwara

Cost-effectiveness of interventions targeting hard-to-reach populations living with HIV in Eastern and Southern Africa

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University

By

Deo Mujwara
BSc, Makerere University, 2011
M.A, Georgia State University, 2015

Director: April D. Kimmel, PhD
Associate Professor, Department of Health Behavior and Policy

Virginia Commonwealth University
Richmond, Virginia
July 2021

Acknowledgements

I am so grateful for the many people that have supported me over the years. First, I would like to thank my dissertation committee chair and advisor, Dr. April D. Kimmel, for her guidance, encouragement, and support. Over the past five years during the Ph.D. program, I have learnt so much and grown into an independent researcher under her supervision. I will forever be grateful. I also thank my dissertation committee members; Dr. Bassam Dahman, Dr. Daniel Nixon, and Dr. Tilahun Adera for lending me their time to discuss my work and for their expert contribution towards my dissertation. I would also like to thank my classmates and peers; Morgan, Heather, Steven, Mandar, Portia, and Muloongo for their support during the program and contributions towards this dissertation.

I have been fortunate to have a group of friends that supported me in multiple ways both in school and outside of school. To Marc and Yasin, whom I met whilst completing my Master's program at Georgia State University, thank you for encouraging me to apply for the Ph.D. program and motiving me to enroll for extra mathematics classes in preparation for the Ph.D. coursework. I would like to thank my friends Bonita, Ezra, Donald, Tracey, Sonia, and Juliana for their support and for always encouraging me to do better in all aspects of my life.

I owe everything I have achieved to my family; they have supported me at every stage of my life, and I am who I am today because of them. To my parents, the Late Mr. Edward Mbaijana and Mrs. Veneranda Mbaijana, thank you for all the sacrifices you made to educate me and my siblings, I will always be grateful. Dad, even though you did not live to see me graduate, your sacrifices were never in vain. I also thank my uncle, the Late Mr. Elly Mugisa and aunt, Mrs. Sylvia Mugisa for their support in the early stages of my education in Uganda. I thank all my

siblings for their support and guidance, and for being good role models by creating a path for me to achieve my goals. In particular, I thank my sister, Kate Mbaijana Mukama and her husband Albert Mukama for all their support. Finally, I thank my brother, Dr. Paul Kagundu, for encouraging me to apply for graduate school in the United States and supporting me whilst in school, and his wife Ann Kagundu, and their three daughters; Krista, Klara, and Kelsie for all their support from the time I came to the United States.

Table of Contents

Abstract

In Eastern and Southern Africa, hard-to-reach populations (e.g., long distance truck drivers and female sex workers), defined as populations that are difficult to interact or engage with due to their unique behaviors and characteristics, are disproportionately affected by the HIV epidemic and are at high-risk of acquiring and transmitting HIV. Further, these populations have substantially low uptake of HIV testing services, and those that have been diagnosed with HIV and on antiretroviral therapy experience high loss-to-follow-up from treatment programs.

Hard-to-reach populations face unique barriers in accessing and utilizing routine HIV care such as provider stigmatization towards sex workers and highly mobile nature of their occupations. Innovative and targeted strategies, which may be resource-intensive, are required to improve their engagement and retention in care. Evidence on cost-effective strategies to improve HIV testing uptake and to reduce loss to follow-up from HIV treatment programs in hard-to-reach populations in Eastern and Southern Africa remains limited.

This dissertation is comprised of three papers examining the cost-effectiveness of HIV testing and loss to follow-up strategies among hard-to-reach populations in Eastern and Southern Africa, using female sex workers and long-distance truck drivers as case study populations and Kenya as a case study setting. In paper one, I conducted a trial-based cost-effective analysis of offering the choice to HIV self-test compared to provider-administered HIV testing among long-distance truck drivers in Kenya. Paper two extended the analysis for paper one by examining the cost-effectiveness of a broad range of alternative HIV testing strategies among hard-to-reach populations in Eastern and Southern Africa using a lifetime Markov model. Seven strategies were examined: i) No testing, ii) voluntary counseling and testing, iii) provider-initiated and -

administered testing, delivery of: iv) self-testing kits, v) self-testing coupons, and vi) HIV testing referral cards in the community using peer-educators, and vii) offering a choice of self-testing at the health facility. In paper three, I applied the same Markov model from paper two to examine strategies to prevent loss to follow-up among female sex workers on antiretroviral therapy in Eastern and Southern Africa. Strategies included: 1) No intervention; 2) Home ART delivery using community-health workers; 3) Home ART delivery using community-health workers plus monthly nutrition supplement; 4) physical and phone-tracing of patients that miss an appointment plus transport refund to the health facility; 5) physical and phone-tracing with free medical care for opportunistic infections; 6) free medical care for opportunistic infections with transport refund to the health facility and free breakfast. Data for paper one came from a randomized controlled trial (n=150, intervention; n=155, control), while data for paper two and three came from peer-reviewed and grey literature. All costs were reported in 2017 international dollars in paper one and 2017 US dollars for paper two and three.

Findings from these studies suggest that investing resources in strategies that offer choices in HIV testing approaches such self-testing at the health facility or in communities using peer educators would improve HIV testing uptake and reaching out to patients on treatment in their communities to deliver them ART drugs may improve retention in ART programs in Eastern and Southern Africa. In paper one, I found that offering a choice of HIV self-testing at the clinic was cost-effective compared to only the provider-administered HIV testing with an incremental cost-effectiveness ratio (ICER) equal to $163. In paper two, delivery of HIV self-testing kits in the community using peer educators was cost-effective (ICER < $600) in both truck drivers and female sex worker sub-populations. Finally, in paper three, delivery of antiretroviral therapy drugs to female sex workers in the community was cost-effective (ICER < $500).

Chapter I: Introduction

In Eastern and Southern Africa, hard-to-reach populations (e.g., long distance truck drivers and female sex workers), which are defined as populations that are difficult to interact or engage with due to their unique behaviors and characteristics,[1] are disproportionately affected by the HIV epidemic, with HIV prevalence of five times more than that in the general population.[2–7] Additionally, hard-to-reach populations are at high-risk of acquiring and transmitting HIV but have substantially low uptake of HIV testing services,[2,5,8–10] and those that have been diagnosed with HIV and on antiretroviral therapy (ART), experience higher (53%) loss to-follow-up (LTFU) from treatment programs[11–18] compared to people living with HIV (PLWH) in the overall population (14%).[19]

Awareness of HIV status has downstream implications for timely linkage to care, ART initiation, and viral suppression, which are critical for achieving the UNAIDS goal of ending the HIV epidemic by 2030.[20] However, hard-to-reach populations face unique barriers that impact their accessibility and utilization of care including HIV testing. For example, truck drivers are highly mobile with irregular work schedules and hours that are discordant with healthcare facility opening hours.[3] Evidence suggests that differentiated approaches such as oral self-administered HIV testing at healthcare facilities[21] and delivery of HIV self-testing kits to targeted populations in the communities[22] are effective at improving HIV testing uptake among hard-to-reach populations due to their acceptability, flexibility and privacy.[23–26] Although the effectiveness of these approaches particularly in hard-to-reach populations is still emerging, little is known about their value for money.

Hard-to-reach populations are not only hard-to-reach but among those able to be reached, diagnosed with HIV, and initiated on ART experience high LTFU from care—opting out of care for more than 180 days without being classified as either dead or transferred to another ART clinic or program.[19] For example, female sex workers are at high-risk of LTFU due to fear of being identified and to provider stigmatization, which may impact routine utilization of care and retention in HIV care among those living with HIV.[27] Identifying cost-effective strategies to reduce LTFU is critical for improving HIV-related morbidity and mortality, preventing new HIV transmission, and for efficiency in allocation of scarce resources. No strategies have been examined to reduce LTFU among hard-to-reach populations in Eastern and Southern Africa.

This dissertation focused on efficiency in allocation of resources for HIV response including HIV testing and reduction of LTFU for those on ART among hard-to-reach populations in Eastern and Southern Africa. HIV response programs in low- and middle-income countries are largely funded by global donors. Given the recent HIV funding constraints, with more than half of high-income countries reducing their funding for HIV response programs to low-income countries,[28] it is critical for local policy makers to allocate scarce resources efficiently by investing in cost-effective strategies.

The goal for this dissertation was to identify cost-effective strategies to diagnose hard-to-reach individuals living with HIV and retain them in HIV care. HIV testing is the first stage along the HIV care continuum, in papers one and two, I examined the cost-effectiveness of strategies to improve HIV testing uptake among those who are undiagnosed and to engage them in care. Once engaged in care and initiated on ART, it is important to retain people living with HIV in care. In

paper three, I examined the cost-effectiveness of strategies to reduce LTFU among those in HIV care and on ART.

Paper one

I conducted a trial-based cost-effectiveness analysis of offering the choice of HIV self-testing at the healthcare facility to increase HIV testing uptake among truck drivers compared to provider-administered HIV testing only, which is the standard of care. This study was based on a randomized controlled trial conducted in 2015 in Kenya among truck drivers at two roadside clinics. In the trial, participants (n=150) in the intervention arm were offered the choice to test for HIV using (1) the provider-administered HIV testing or (2) HIV self-testing under the supervision of a provider. Those who declined the two options were offered a third choice (3) HIV self-testing at home without supervision of a provider. Participants (n=155) in the control arm were offered the provider-administered HIV testing only. The primary outcome in the trial was HIV testing uptake, defined as a participant that accepts to be tested for HIV. Participants in the intervention (CHIVST) arm had significantly higher odds of testing for HIV compared to the control (SOC) arm (2.8, 95% Confidence Intervals [1.5, 5.4]).[21]

Effectiveness data came from a randomized-controlled trial of CHIVST versus provider-administered blood (finger-prick) testing only at a roadside wellness clinic in Kenya. Economic cost data came from the literature, reflecting a societal perspective. Generalized Poisson and linear gamma regression models were used to estimate the effectiveness and incremental costs (2017 I$), respectively; incremental effectiveness was reported as the number needed to receive CHIVST for an additional HIV test uptake. I evaluated the performance of incremental cost-effectiveness ratios (ICERs) using a willingness-to-pay threshold of 3xGDP per capita for Kenya

and assessed uncertainty using deterministic sensitivity analyses and the cost-effectiveness acceptability curve.

HIV test uptake was 23% more likely for CHIVST versus SOC, with six individuals needed to receive CHIVST for an additional HIV test uptake. The mean cost per patient was over fourfold higher for CHIVST versus SOC (I$35.59 vs I$8.84). CHIVST was I$ 163.77, 95% CI [151.57, 175.37] per additional HIV test uptake compared to SOC. Self-test kit and cell service were the main cost drivers of the ICER, with findings robust even in a worst-case scenario (highest possible costs). The probability of CHIVST being cost-effective approached one at willingness-to-pay of I$250. CHIVST was cost-effective at a low willingness-to-pay threshold ($163), suggesting that CHIVST is a highly efficient use of resources for improving HIV test uptake among high-risk sub-populations. Policies supporting CHIVST and similar sub-populations may expedite achievement of international targets.

Paper two

In paper two, I extended the analysis for the first paper and examined the cost-effectiveness of a broad range of alternative HIV testing strategies in hard-to-reach populations in Eastern and Southern Africa. Seven alternative HIV testing strategies were examined: i) No testing; ii) voluntary counseling and testing (VCT);[29] iii) provider-initiated and -administered testing and counseling (PITC);[21] delivery of: iv) self-testing kits, v) self-testing coupons, and vi) HIV testing referral cards in the community using peer-educators;[22] and vii) offering a choice of self-testing at the health facility in addition to provider-initiated and -administered testing.[21] I developed a lifetime Markov model to examine life years saved, disability adjusted life years (DALYs) averted, economic costs, and incremental cost-effectiveness ratios in a cohort of 30-year-old

high-risk and hard-to-reach men and women living with HIV. Economic costs were estimated from a societal perspective and reported in 2017 US dollars. The cost-effectiveness of strategies was determined according to the willingness to pay threshold equivalent to 3xGDP per capita for Kenya in 2017 (3x$1,570 = $4,710). Future costs and health benefits were discounted at an annual rate of 3%. Deterministic sensitivity analysis was performed to assess uncertainty in model parameter inputs.

I found that the Kit delivery strategy was cost-effective and had the highest cost and life expectancy at 30 years and lowest DALYs lost among female sex workers (FSWs) and truck drivers. Total costs ranged from $1,400 to $6,100 and $1,400 to $4,951 in the "No testing" and kit delivery strategies among FSWs and truck drivers, respectively. More DALYs were lost in the "No testing" strategy (21.93 and 22.11) compared to the Kit delivery strategy (12.70 and 14.77) among FSWs and truck drivers, respectively. The kit delivery strategy was cost-effective compared to alternative HIV testing strategies among both FSWs and truck drivers with an ICER of less than $600 per DALY averted. The kit delivery strategy compared to No testing, cost more but averted 9.23 and 7.34 DALYs and saved 8.88 and 7.13 life years among FSWs and truck drivers, respectively. Delivery of self-testing kits in the community was cost-effective among FSW when 75% or more are reached. Variations in parameter inputs did not change the main findings among truck drivers. Using peer-educators to deliver HIV self-testing kits in the community is a cost-effective strategy to improve HIV test uptake in populations that are hard to reach and at high-risk of acquiring and transmitting HIV.

Paper three

In the third paper, I examined the cost-effectiveness of alternative strategies to reduce LTFU among female sex workers on ART in Eastern and Southern Africa. Using a similar Markov model from paper two, I projected costs and DALYs for six alternative strategies: 1) No intervention; 2) Home ART delivery using community-health workers; 3) Home ART delivery using community-health workers plus monthly nutrition supplement; 4) physical and phone-tracing of patients that miss an appointment plus transport refund to the health facility; 5) physical and phone-tracing with free medical care for opportunistic infections; 6) free medical care for opportunistic infections with transport refund to the health facility and free breakfast. The analysis was conducted from a payer perspective with future DALYs lost and costs discounted at 3%. Costs were valued in US dollars and inflation-adjusted to 2017 currency year. The ICER was used to assess the relative performance of the strategies, with the cost-effectiveness of a given strategy determined according to a threshold of 3x the GDP per capita for Kenya in 2017 (3x$1,570 = $4,710). Uncertainty in inputs was assessed using probabilistic sensitivity analysis.

In the base case analysis, total costs and DALYs lost per strategy ranged from $2,994 to $10,022 and 11.52 to 9.27 for No Intervention and ART delivery plus nutrition supplement, respectively. ART delivery was cost-effective compared to alternative strategies with an ICER of $470 per DALY averted. Although ART delivery with nutrition supplement had lower DALYs lost (9.27), total costs were substantially higher compared to the next best alternative, ART delivery ($10,022 vs $5,173). Tracing with transport refund had higher costs ($4,386 vs $3,460) and DALYs lost (11.05 vs 10.55) compared to the next best alternative, ART delivery, and was absolutely dominated. Strategies: tracing with free medical care for opportunistic infections and

transport refund with free medical care for opportunistic infections plus breakfast had lower costs ($4,606 and $5,173) but higher DALYs lost (10.51 and 10.35) and were extendedly dominated by ART delivery with nutrition supplement that had higher costs ($10,022) but with lower DALYs lost (9.27). FSWs remain disproportionately impacted by HIV with high rates of LTFU from ART programs among those on treatment. I found that delivering ART drugs to FSWs in their homes, places that they frequent, or community centers was a cost-effective strategy to reduce LTFU among patients in FSWs in ART programs in Eastern and Southern Africa

Chapter II: Choice of Self-Administered Oral HIV Testing among Long Distance Truck Drivers in Kenya: A Trial-based Cost-effectiveness Analysis

Introduction

The HIV epidemic in sub-Saharan Africa remains a major global public health challenge, with over 1 million people living with HIV in the region unaware of their HIV status.[30] Early awareness of HIV status has downstream implications along the care continuum, including timely linkage to care, antiretroviral therapy (ART) initiation, and viral suppression, which are critical for achieving the international targets that can end the HIV epidemic.[31] However, uptake of HIV testing services is low, particularly in sub-populations that are disproportionately impacted by HIV and at high risk of transmission.[2,5,8] To improve and sustain high HIV awareness levels in these sub-populations, targeted, innovative HIV testing strategies are needed. These strategies may require more resources,[32] a significant challenge when HIV funding is limited.[33]

Long distance truck drivers in the region are at high risk of acquiring and transmitting HIV, but have relatively low HIV testing uptake.[2,5,8] For example, from 2013 to 2015, only 32% of 13,252 patients that visited the clinics utilized HIV-related services including HIV testing.[8] In 2018, the North Star Alliance—an organization providing healthcare services to mobile workers and people they interact with along truck routes—reported that only 34% of 289,078 services offered at wellness centers were HIV testing,[34] indicating that HIV testing uptake is still sub-optimal even when healthcare facilities are geographically close to places where truckers congregate such as truck stops.

This sub-population has unique characteristics contributing to their high HIV risk and low-test uptake. Truck drivers travel for many days away from their main partners, which provides opportunities to engage with other partners and commercial sex workers,[35–37] increasing their HIV risk.[38] Truck driver mobility coupled with irregular work schedules and discordance between work hours and healthcare facility opening hours limit the accessibility and utilization of healthcare services, including routine HIV testing.[39] Further, men are less likely to test for HIV and, given that majority of truck drivers are men, there is an additional gender barrier to HIV testing uptake.[40] Standard of care approaches for HIV testing, such as clinic-based, provider-administered testing, do not address these barriers.

Emerging evidence suggests that patient-centered care delivery, including self-administered oral HIV testing,[41] improves HIV test uptake among truck drivers.[21,42] One approach—self-administered oral HIV testing—has generated considerable interest due to its acceptability, flexibility and user privacy.[23–26] The introduction of HIV self-testing to compliment the traditional standard of care—provider administered HIV testing—has improved uptake of HIV testing, both in the general population[23,43] and among high-risk sub-populations including truck drivers[21,22,42] and sex workers[22,44] in sub-Saharan Africa.

While HIV self-testing has been found to be effective,[21] evidence on cost[32] and cost-effectiveness[45–48] is limited and no cost-effectiveness study exists among high-risk sub-populations including truck drivers. Examining cost-effectiveness is particularly pertinent in resource-limited settings where in-country resources are often insufficient to implement all HIV response programs and may potentially worsen since the global HIV funding in recent years has decreased or remained flat[33,49] and emerging external shocks (e.g., COVID-19) threaten the

availability of ongoing donor support.[50] This funding shortfall and ongoing future financing challenges underscore the need to prioritize available resources for cost-effective interventions.

In Kenya, a recent randomized controlled trial found that offering truck drivers the choice of self-administered oral HIV-testing versus provider-administered testing at an easily accessible roadside wellness clinic resulted in HIV testing uptake nearly three times that of provider-administered testing only, suggesting HIV testing approaches that are tailored to individual need or preference in this sub-population are effective.[21] While this trial found the intervention effective, there is little knowledge of its value for money in this sub-population. This study examined the incremental cost-effectiveness of offering the choice of HIV self-testing (CHIVST) compared to provider-administered HIV testing, the standard of care (SOC) only, among truck drivers presenting for care at a roadside wellness clinic in Kenya. Two research questions are examined: 1) are economic costs of offering the CHIVST greater than the SOC? 2) is offering the CHIVST a cost-effective intervention compared to the SOC?

Overview of the trial

In 2015, a randomized controlled trial was conducted at two roadside wellness clinics in Kenya to compare HIV testing uptake among truck drivers offered the choice of self-administered rapid oral HIV-testing compared to uptake among those offered provider-administered rapid blood (finger-prick) HIV testing only, the standard of care (SOC).[21] In the intervention arm, truck drivers (n=150) were offered the choice to test for HIV using 1) the SOC HIV testing or 2) self-administered oral HIV-testing under the supervision of a provider. If the truck driver declined the two options, they were offered a third option; 3) self-administered oral HIV-testing outside the clinic (at home) without supervision of a provider but with phone-based support and post-test

counseling. In the control arm, truck drivers (n=155) were offered only the SOC HIV testing. The adjusted odds ratio (2.8, 95% CI [1.5, 5.4]) of HIV testing uptake in the intervention arm were significantly higher compared to the control arm.[21]

Methods

Overview

I conducted a trial-based incremental cost-effectiveness analysis of offering the CHIVST to increase HIV testing uptake among truck drivers in Kenya compared to the SOC. Data from the trial was used to estimate the effectiveness and incremental effectiveness of offering the CHIVST, with incremental effectiveness estimated as the number of participants needed to receive the CHIVST for an additional truck driver to test for HIV. Economic cost data were derived from the literature according to the societal perspective, which considers economic costs for both the payer and the patient. Incremental cost-effectiveness ratios were calculated, with the economic performance of the CHIVST intervention evaluated according to a threshold of 3 x gross domestic product (GDP) per capita in Kenya. I assessed uncertainty using deterministic sensitivity analyses and a cost effectiveness acceptability curve. This study was reviewed by the Virginia Commonwealth University Institutional Review Board and designated as exempt to regulations of human subject (Reference Number: HM20015160).

Costing Approach

Economic cost data came from the literature. Studies conducted in Kenya were prioritized, with data from studies conducted in lower-middle-income countries in sub-Saharan Africa also considered if they were contextually relevant to the trial. I restricted the search to studies with data collected less than 10 years from the year of the trial, since more recent cost data sources

reflect current healthcare delivery systems and utilization patterns, which tend to vary overtime. Costs were adjusted for inflation using the World Bank GDP deflator[51] to account for changes in costs over time and reported in 2017 international dollars (I$),[52] which enables comparison of costs across multiple settings (countries) and captures differences in local currency purchasing power. Micro- and gross costing approaches were used to assign per-patient costs. Micro-costing enables more precise estimation of costs (medical, labor and patient time) for resources utilized[53] by multiplying the quantity of resources and the unit cost. Gross-costing aggregates costs (equipment, capital, cell phone service, overhead costs) for an intervention to estimate the per patient cost for resources that cannot be explicitly allocated at the patient level based on individual utilization.[54]

Data

Costs were estimated based on the HIV testing procedure (SOC or oral self-test) performed and/or the setting (clinic only or clinic and home). Medical costs included the cost of HIV testing kits (OraQuick for self-test, I$ 15.52[55]; Colloidal Gold test for SOC, I$ 1.43[56]) as well as medical supplies (self-test, I$ 0.26; SOC, I$ 0.42) used in the HIV testing process at the clinic,[57] which varied based on the HIV testing procedure. Medical supplies considered are listed in the supplementary material, Table S11. I emphasize that the cost of the SOC test kit was only considered in the sensitivity analysis, since SOC kits were provided to North Star Alliance by the Kenyan Ministry of Health and thus the trial did not incur the cost for these kits.[55] Labor costs included salaries for the nurse per-patient (self-test, I$ 2.84; SOC, I$ 2.27),[55] non-clinical healthcare facility staff (I$ 1.10 per-patient that tested from the clinic only; I$ 0.47 per-patient that visited the clinic but tested from home)[32] and one-time training (I$ 0.09 per-patient in the intervention arm) for nurses on how to use the HIV self-testing kit.[55] Equipment (cell phone, I$

2.47 per-patient in the intervention arm),[55] healthcare facility site (I$ 1.72 per-patient that tested from the clinic only; I$ 0.74 per-patient that visited the clinic but tested from home),[32] overhead (I$ 4.24 per-patient that tested at the clinic only; $I 2.26 per-patient that visited the clinic but tested from home)[32] and cell phone service (13.65 per-patient in the intervention arm)[55] costs were allocated using the gross-costing.[54] Patient time spent at the healthcare facility or home testing for HIV, including pre- and post-test counseling, was considered time lost that could have been alternatively used to economically benefit the patient; patient time (oral self-test, I$ 3.13; SOC, I$ 2.51) was calculated as the product of the time spent testing for HIV and the hourly wage of a truck driver, estimated based on income of participants in trial.[21] The HIV testing process took 40 and 50 minutes for participants that tested using the standard of care and oral self-administered test, respectively.[55]

Statistical analysis

I conducted analysis using two statistical models. A generalized linear Poisson regression model with a robust variance was used to estimate the effectiveness and incremental effectiveness of CHIVST and a generalized linear gamma regression model to estimate the incremental cost. Equation 1 below shows the generalized linear model for estimating effectiveness, incremental effectiveness, and incremental costs of the CHIVST.

$$Outcome_i = \beta_o + \beta_1 Choice_i + \boldsymbol{X_i B} + u_i \quad (1)$$

where, $Outcome_i$ represents HIV testing uptake or cost assigned to the i^{th} patient; $Choice_i$ is a binary variable equal to 1 if a patient is assigned to CHIVST arm and equal to 0 if assigned to the SOC; β_1 is the coefficient of interest—effect of CHIVST on the outcome. $\boldsymbol{X_i}$ and $\boldsymbol{B}$ are vectors and coefficients, respectively, of the control variables. I controlled for four variables that have

been found to impact HIV testing uptake[40] and/or are contextually applicable to the study. These include the healthcare facility (the trial was conducted at two facilities), age of the participant, whether the participant visited the clinic to purposely test for HIV, and whether they have paid of sex in the last 6-months prior to the date of the clinic visit.

Effectiveness and Incremental Effectiveness

I estimated the effectiveness of CHIVST as the relative risk of HIV test uptake in the CHIVST arm compared to the SOC arm. The incremental effectiveness was estimated as the Number Needed to Treat (NNT)[58] and interpreted as the number of truck drivers who need to be offered the CHIVST for an additional driver to get tested for HIV. The NNT approach was selected as an alternative to more traditional measures of incremental effectiveness such as the disability adjusted life years (DALYs) averted because the primary outcome (HIV test uptake) in the trial was an intermediate outcome and the trial time period (3 months) was too short to estimate DALYs. Using DALYs as a measure of health benefit would not have generated meaningful differences between trial arms and multiple assumptions would be required to estimate when considering a longer time horizon without developing a mathematical model.

NNT was derived in four steps:

- Step 1: Predict the absolute risk of HIV testing uptake per patient.
- Step 2: Calculate the mean per-patient absolute risk for HIV testing uptake per trial arm.
- Step 3: Estimate the mean per-patient absolute risk difference between trial arms
- Step 4: Take the reciprocal of the mean absolute risk difference to calculate NNT.

Economic Costs and Incremental Costs

Economic costs per-patient by trial arm were calculated by multiplying resources utilized at the individual level with unit costs and summarized using the mean with 95% confidence intervals (CIs), since decisions are made based on expected costs.[59] Incremental costs reflect the difference in mean per-patient costs between the CHIVST and SOC arms.

Incremental Cost-effectiveness Ratio (ICER)

The ICER was calculated as the product of the incremental cost and incremental effectiveness. Conventionally, the ICER is calculated by dividing the incremental cost (ΔC) by incremental effectiveness (ΔE) i.e., $ICER = \frac{\Delta C}{\Delta E}$. When using the NNT approach, however, the incremental effectiveness (NNT) is calculated as the reciprocal of the mean per-patient absolute risk difference ($\frac{1}{\text{RD}}$). Thus, the ICER is calculated as the product of ΔC and NNT ($\text{ICER} = \Delta\text{C} * \frac{1}{\text{RD}} = \Delta\text{C} * \text{NNT}$). I calculated the 95% CI for the ICER using non-parametric bootstrapping method since the data (cost and effectiveness variables) were not normally distributed.[59]

A threshold of 3 x GDP per capita (2017) for Kenya was used to determine the cost-effectiveness of the CHIVST.[60] The threshold represents the maximum willingness-to-pay (WTP) value for the additional health benefit gained from the CHIVST and is used to determine whether CHIVST presents a good value for money. The willingness-to-pay threshold is used as guide for cost-effectiveness decision making, in addition to other factors including local competing priorities, intervention affordability, and feasibility of implementation, which are not accounted for in the willingness-to-pay threshold.[61,62] I also assessed a lower threshold (GDP per capita) to account for differences in affordability across settings given that the threshold of 3xGDP per capita may be too high for low-income countries with resource constraints and high opportunity cost.[61–64]

Missing data

In the analytic sample, only 9 (3%) participants were missing at least one data point. Using Little's test, I examined the randomness assumption about the missing data and found that the data were missing completely at random (MCR) across trial arms,[65] implying that the missing data were not systematically correlated with other variables across trial arms. Participants (9) with data MCR were then excluded from the analysis since they had no significant impact on the study outcomes.

Uncertainty

I assessed the impact of variation in costs on the ICER using deterministic sensitivity analyses (one-way and multi-way sensitivity analysis)[60] and uncertainty in the base case ICER using the cost-effectiveness acceptability curve.[66,67] One-way sensitivity analysis identified the main cost drivers of variation in the ICER, with the results reported using a tornado diagram, which summarizes of the range of ICERs due to variation in unit cost estimates. Multi-way sensitivity analysis assessed the robustness of the study findings by varying unit costs considering the best- and worst-case scenarios. The worst-case scenario was defined according to the upper bound values, while the best-case scenario was defined as the lower bound values of each economic cost. Although these scenarios may be unrealistic in practice, they can provide insight into the policy impact of the most optimistic and pessimistic cases in cost variation. I assessed uncertainty in the base case ICER using the cost-effectiveness acceptability curve. The acceptability curve summarizes the probability an intervention is cost-effective at different willingness-to-pay thresholds. I generated the acceptability curve from a joint distribution of incremental costs and incremental effects, which was estimated using non-parametric bootstrapping.[67]

Results

Base case analysis

CHIVST significantly increased HIV testing uptake among truck drivers. More than 87% (130/149) of truck drivers in the CHIVST arm tested for HIV compared to 73% (114/156) in the SOC arm. Truck drivers in the CHIVST arm were 23% more likely to test for HIV relative to those in the SOC arm. The incremental effectiveness, measured as the NNT, was 6.25, 95% CI [5.00, 8.33], meaning that for every six truck drivers offered the CHIVST, one additional driver will test for HIV.

The mean cost per-patient (Table 1) was more than four times higher in the CHIVST (I$ 35.59 vs SOC (I$ 8.84) arm. Majority (>70%) of the mean per-patient cost in the CHIVST was attributed to the cell phone service (I$ 12.03), price of HIV testing kit (I$ 10.12) and overhead (I$ 3.59), while in the SOC arm, it was attributed to the overhead (I$ 3.06), patient time (I$ 1.81) and nurse salary (I$ 1.64). The incremental cost was I$26.20, 95% CI [23.32, 29.09], representing the adjusted difference in the mean per-patient costs between the CHIVST and SOC arm. In the base case analysis, the ICER for offering the CHIVST was I$163.77, 95% CI [151.57, 175.37], meaning that offering truck drivers the CHI

VST costs I$163 per additional HIV test uptake compared to the SOC.

Uncertainty

Our findings were robust to variations in economic costs and effectiveness of CHIVST. The cost of cell phone service and HIV self-testing kit were the key cost drivers and had the largest impact on the ICER (Figure 1), although the upper bound of the ICERs for both sensitivity analyses fell well below traditional willingness-to-pay thresholds. I examined the potential impact the HIV self-testing kit price reduction to US $2, based on the Bill and Melinda Gates Foundation agreement with manufactures and low-income countries.[68] With the reduced price, CHIVST was cost-effective at a much lower willingness-to-pay value (I$ 119 vs I$ 163). Offering the CHIVST was still cost-effective in both the best- and worst-case scenarios (results reported in the supplementary material).

CHIVST increases both costs and effectiveness but is cost-effective at low willingness-to-pay thresholds. The joint distribution shows (Figure 2) that all the data points on the cost-effectiveness plane are in the northeastern quadrant. This indicates that offering the CHIVST increases both costs and HIV testing uptake and that there is less uncertainty in the cost per additional HIV test performed since all the data points are clustered in the same quadrant. The probability of CHIVST being cost-effective compared to the SOC is almost equal to 1 when the willingness-to-pay value is greater than I$ 250 (Figure 2), which is much lower than even the minimum willingness-to-pay threshold considered of I$3,258 (1xGDP per capita).

Discussion

HIV status awareness remains low, particularly in high-risk sub-populations in sub-Saharan Africa, and improving HIV test uptake may require efficient, innovative, and targeted strategies.

I examined the cost-effectiveness of offering the CHIVST to truck drivers at a roadside clinic in Kenya compared to the SOC. I found CHIVST was effective—increasing the probability of HIV testing uptake by 23%—and cost-effective when the decision maker is willing to pay I$163 per additional truck driver tested for HIV per year.

CHIVST costs more, with the mean cost of an HIV test uptake more than four times higher, but it is cost-effective, compared to the SOC. Although participants in the trial did not pay for the testing kits, cost remains one of the main barriers to accessing healthcare services, including HIV testing, and truck drivers consider cost as the strongest factor for the choice of HIV test.[69] However, CHIVST was cost-effective compared to the SOC at willingness-to-pay of I$163 for an additional HIV test uptake, which is substantially lower than the willingness-to-pay threshold used for Kenya ($I9,774), suggesting that although CHIVST costs more, it has a higher health benefit and offers good value for money. Our findings were robust to extreme scenarios when I considered higher bounds of all costs, which are driven primarily by the cost of the cell phone service and HIV self-test kit in the CHIVST arm. I also considered a scenario with a self-administered oral HIV test kit costing US $2 based on Bill and Melinda Gates Foundation agreement with manufactures and low- and middle-income countries,[68] but it did not change the policy conclusion.

This study provides a novel contribution to emerging broader literature on the effectiveness and cost-effectiveness of HIV self-testing, which has largely focused on the overall population of people living with HIV.[45–47] While little has been done to examine the cost and cost-effectiveness of HIV self-testing among truck drivers, previous work conducted a costing analysis and found self-administered oral HIV testing per test costs more (double) than routine

facility-based testing (the standard of care),[32] which is consistent with the current study. However, previous work did not examine the cost-effectiveness, and costs were only estimated from a provider perspective.[32] To our knowledge, this is the first study to examine the cost-effectiveness of offering the CHIVST compared to the SOC among truck drivers in this setting. In Zimbabwe[47] and Malawi,[45] HIV self-testing in the general population was cost-effective compared to the provider administered HIV testing. Similar to findings in this study, the cost of HIV self-testing kit was higher compared to the provider-administered HIV testing kit and was one of the key variables impacting the cost-effectiveness of HIV self-testing. In Zimbabwe, HIV self-testing was cost-effective when efficacy was at least 20%,[47] which is comparable to the effectiveness (23%) of CHIVST. Only one study from sub-Saharan Africa included a high-risk or hard-to-reach sub-population (female sex workers) and found HIV self-testing to be cost-effective when targeting female sex workers and in settings with high prevalence of undiagnosed HIV.[46] Based on previous work, more than 80% of HIV-infected truck drivers were unaware of their HIV status in some settings,[5] suggesting a high likelihood of HIV self-testing being cost-effective in this sub-population. Although our study findings are broadly comparable with the HIV self-testing literature, they should be interpreted with caution since I examined the cost-effectiveness of offering a choice of HIV self-testing in addition to the SOC test and not of offering only HIV self-testing. A large proportion of truck drivers in the CHIVST arm still chose the standard of care test, suggesting that some truck drivers may choose not to test if offered only HIV self-testing. In addition, I considered a short time horizon (3 months) and different effectiveness measure compared to previous work done in the overall population of PLWH that used mathematical models and considered a 20-year time horizon and long-term measures of effectiveness (e.g., DALYs).[45–47]

Findings indicate that differentiated care—in this case, choice of self-administered oral HIV testing for high-risk sub-populations—is an effective and cost-effective strategy to improve HIV test uptake. In Eastern and Southern African, HIV testing uptake remains low despite healthcare services being geographically and temporally convenient.[34] For example, roadside wellness centers, such as those run by North Star Alliance, offer a broad menu of healthcare services, including HIV testing and treatment, close to truck stops where truck drivers, sex workers and roadside community residents congregate and interact and at off hours when these groups are more likely to have time to seek services, but test uptake is low.[34] CHIVST provides a cost-effective potential solution to some of the limitations (e.g., lack of flexibility and privacy) of the SOC HIV testing offered at the roadside wellness clinics.[70]

Our results contribute to a substantial gap in knowledge on efficient strategies to improve HIV status awareness among truck drivers and other high-risk or hard-to-reach sub-populations in the sub-Saharan Africa, a region with more than half of the world's HIV population. In Kenya and Uganda, along the trans-African highway, sexual interaction between transport workers and communities at truck stops was estimated to contribute up to 4,148 new HIV infections in a year.[38] International and local policy makers could implement efficient strategies such as CHIVST that improves HIV testing uptake as one strategy to reduce onward HIV transmission by diagnosing people early and engaging them in HIV care. HIV-positive individuals aware of their HIV status are likely to have fewer sexual partners and to use condoms compared to those unaware of their status,[71] thus reducing onward HIV transmissions. But, despite the increase in the number of countries (from 6 to 77 countries in 2015 and 2019, respectively) in support of HIV self-testing policies, implementation and integration of HIV self-testing in national HIV programs remains a challenge,[41] with less than 37% (28/77) of the countries at the

implementation stage.[72] Findings from this study provide supporting evidence to guide policy makers in their decision making and implementation of HIV self-testing, particularly in high-risk sub-populations.

This study had some limitations to consider in its interpretation. First, I did not account for future costs and health benefits beyond the intervention period (3 months). For example, cost of antiretroviral drugs and health benefits such as disability-adjusted life years averted that account for long-term health benefits for truck drivers who were diagnosed with HIV and initiated on ART. Additionally, the effectiveness and incremental effectiveness were estimated using an intermediate outcome (HIV testing uptake), which limits comparability with cost-effectiveness studies in literature that used traditional measures (e.g., disability adjusted life years). Although using a mathematical model with a longer time horizon would account for future consequences, a trial-based cost-effectiveness analysis provides evidence to inform policy decisions which are usually implemented on short term basis (e.g., 1 to 5 years). Second, CHIVST was offered in a healthcare facility setting among truck drivers already seeking care, who may have different healthcare utilization behaviors compared those not accessing the healthcare facility. However, the intervention is likely to be more effective in the outside setting. Third, economic costs data were derived from literature since I did not collect data on the exact costs incurred during the trial. However, I conducted sensitivity analyses to account for uncertainty in cost estimates and the findings were robust.

As countries aim to achieve UNAIDS targets with limited resources available, innovative, and targeted cost-effective strategies are imperative, particularly for sub-populations at high risk of acquiring and transmitting HIV. This study finds offering self-administered oral HIV testing as a

testing choice at roadside wellness clinics in Kenya to be a highly efficient use of resources compared to the SOC of offering provider-administered blood-based HIV testing only. Future studies should examine the cost-effectiveness of self-administered HIV testing outside the clinic setting among high-risk sub-populations and consider the long-term costs and health benefits of HIV testing.

Chapter III: Cost-effectiveness of Alternative HIV Testing Strategies among Hard-to-Reach Populations in Eastern and Southern Africa

Introduction

HIV testing remains substantially low in populations that are hard-to-reach and at high-risk of transmitting HIV.[2,5,8–10] These populations that are difficult to interact or engage with due to their unique behaviors and characteristics, and as result, are hard to reach and engage in care.[1] Low HIV testing has downstream consequences for engagement in HIV care, new HIV infections[73] and may halt the global target of ending the HIV epidemic by 2030.[20]

Female sex workers (FSWs) and long-distance truck drivers (truck drivers), particularly in Eastern and Southern Africa, have been hard-to-reach and are disproportionately impacted by HIV, with prevalence more than five times that of the general population in some settings.[2,5,7] Traditional facility-based HIV testing approaches may not to reach these populations because of the unique barriers they face in accessing care.[3,10] For example, truck drivers are highly mobile due to their occupation and usual opening hours at healthcare facilities are unfavorable for routine health care utilization.[74,75] FSWs face various barriers including provider stigma and discrimination, which may negatively impact their willingness to seek HIV prevention services and care.[76,77]

Innovative strategies targeting high-risk and hard-to-reach populations have shown improved uptake of HIV testing but require more resources[21,22] and their cost-effectiveness remains unknown, despite the urgent need for efficient allocation of limited HIV funds. Globally, HIV funding has stagnated, and over the past decade, funding from high-income countries has

declined by more than $1 billion and future funding remains uncertain.[28] This increases the burden on low-income countries to close the ongoing and increasing funding gap.[78] To ensure long-term sustainability of the HIV response programs, resources need to be allocated efficiently by investing in cost-effective strategies. In this study, I examined the cost-effectiveness of alternative HIV testing strategies among female sex workers and long-distance truck drivers in Eastern and Southern Africa.

Methods

Overview

I used a Markov model to examine the cost-effectiveness of seven HIV testing strategies in a hypothetical cohort of 30-year-old[21,22] undiagnosed truck drivers and FSWs living with HIV. The primary outcomes included economic costs, life expectancy, disability-adjusted life years (DALYs) lost and incremental cost-effectiveness ratios (ICERs). The analysis was conducted from the societal perspective over a lifetime time horizon, with future economic costs and DALYs discounted at 3%.[60] Economic costs were valued in US dollars ($) and inflation-adjusted to 2017 currency year. The relative performance of the HIV testing strategies was assessed using the ICER (2017 $/DALYs averted), and the cost-effectiveness determined based on the willingness to pay threshold equivalent to 3xGDP per capita for Kenya in 2017 ($4,710),[60] although lower thresholds were also assessed to account for differences in affordability and willingness to pay across settings.[61–64,79] I assessed uncertainty in parameter inputs using deterministic sensitivity analysis.

Strategies

Seven strategies were examined (Table 2): i) No testing; ii) voluntary counseling and testing (VCT);[29] iii) provider-initiated and -administered testing and counseling (PITC);[21] delivery of: iv) self-testing kits, v) self-testing coupons, and vi) HIV testing referral cards in the community using peer-educators;[22] and vii) offering a choice of self-testing at the health facility in addition to provider-initiated and -administered testing.[21] Strategies were classified (community, facility and combination of both facility and community) based on the setting of the initial contact with target population and setting for HIV test uptake. Community-based strategies had higher costs, probability of reaching the target population and HIV test uptake compared to facility-based strategies.

Model Structure

I used a Markov model with mutually exclusive health states—a single state of health where one event occurs per time period—but with probabilities that collectively sum up to 1. State-transition probabilities are exponentially distributed (constant) and conditional on current but not previous health states.[80] The model has 24 health states defined by HIV disease progression and engagement in clinical HIV care (Figure 3).[81] The clinical stages of HIV disease progression were defined as follows: Asymptomatic Early (corresponding with CD4 count >500 cells/μL); Asymptomatic Late (corresponding with CD4 count >350 - 500 cells/μL); Symptomatic (CD4 count >200-350 cells/μL); and AIDS (CD4 count $\leq$200 cells/μL)). Disease stages defined based on CD4 stratification is consistent with current mathematical modeling literature and enables estimation of benefits and costs for diagnosis, linkage and ART initiation at early vs later stages of the disease.[82,83] The model did not include health states reflecting viral suppression due to data limitations among people living with HIV in these settings. Further, the differences in health

benefits across strategies attributed to viral suppression in the long run would be minimal after discounting. I assumed that individuals who were consistently on ART (first or second line) achieved viral suppression. Engagement in HIV care was characterized as undiagnosed, diagnosed, linked to care, on first line ART, on second-line ART, lost from care, and death. Although current guidelines recommend test and treat, evidence shows delays in linkage and ART initiation in this setting.[84]

HIV diagnosis cascade (Figure 4) implemented in this study followed the HIV testing algorithm in Kenya.[85] The cohort undergoing HIV testing received an initial test and if the test was a reactive test, a confirmatory test was performed, with a tiebreaker test used when the initial test was reactive, but the confirmatory test had a negative result. Figure 4 shows pathways with fraction of the cohort moving from undiagnosed to diagnosed health states. The sensitivity of the initial HIV test was strategy specific, but the confirmatory test and tie-breaker test was the same across all strategies. Strategies (Kit Delivery, Coupon Delivery and HIVST Choice) that offered the oral self-administered test used the Oral Sure OraQuick test, with sensitivity (95% confidence interval) of 92% (66.0 – 99.0).[86,87] Strategies (Referral card, HIVST Choice, PITC, VCT) that offered the blood-based provider-administered test used KHB colloidal Gold test, sensitivity (95% CI) = 100.0% (97.4 – 100.0).[85] Sensitivity of the confirmatory (First Response 1-2.0) and tiebreaker (Uni-Gold) test were 100.0% (97.4 – 100.0) and 96.4% (91.8 – 98.8),[85] respectively. Consistent with the current HIV care guidelines in Kenya, those diagnosed with HIV were linked to care and initiated on treatment irrespective of the disease stage.[88] Death could occur in all health states due HIV- or non-HIV-related causes with variations in the probability of death based on disease stage, engagement in HIV care[89] and background mortality.[90] The model (Figure 3) was implemented in TreeAge Pro software version 2021.

I made the following key assumptions: 1) I assumed FSWs and truck drivers older than 49 years were not considered part of the high-risk and hard-to-reach populations and were comparable to the overall population of people living with HIV (PLWH). Based on previous research, a significant majority (>85%) of truck drivers and FSWs are below 50 years and I assumed they change occupations.[8,42,70,91] 2) HIV testing strategies that used peer-educators reached all the targeted population since they work in smaller groups and are likely to trace, follow-up and gain trust of their peers.[92] 3) All truck drivers and FSWs that got a reactive initial HIV test and a confirmatory test were linked to care and initiated treatment.

Parameter inputs

Data for parameter inputs (Table 3): HIV test uptake, disease progression, engagement in HIV care and death came from published and grey literature, and were converted to monthly probabilities to reflect the model cycle length.[93] The initial distribution of 30 year-old, undiagnosed individuals living with HIV came from a cohort study of newly diagnosed HIV individuals in Kenya.[94] I varied this distribution in sensitivity analysis to reflect limited data on CD4 cell count distribution among truck drivers and FSWs living with HIV in sub-Saharan Africa.

HIV test uptake data came from two randomized controlled trials (RCT) conducted in Uganda and Kenya among FSWs (Intervention = 610; Control = 316)[95] and truck drivers (Intervention = 150; Control=155),[21] respectively, and two studies with evidence on HIV test uptake among truck drivers and FSWs for the VCT strategy (standard of care).[21,96] HIV test uptake varied based on setting, sex, age, HIV disease stage and, with community-based (vs facility-based) strategies reaching more people[97,98] and women testing more than men except in older adults above 50

years.[99] Further, those at AIDS stage were more likely to test since they tend to be sicker compared to those in non-AIDS stage.[100]

After the initial reactive test, a confirmatory test was required before linkage to HIV care and ART initiation. I assumed perfect (100%) receipt of a confirmatory test in facility-based testing and 90% for community-based testing with peer educators.[92,101] Data for timely (within 30 days of HIV diagnosis) linkage to care and ART initiation came from a longitudinal study on "test and treat" in sub-Saharan Africa.[102] Data for loss-to-follow-up (LTFU) came from a retrospective study among FSWs in Rwanda.[14] HIV natural history data came from a community-based HIV testing study in South Africa, which estimated disease progression by fitting data to a pooled-analysis of observational cohort studies in Africa.[83] Mortality data for PLWH who were not on ART came from a longitudinal study in South Africa.[89] I assumed mortality reduces by 58% among PLWH and on ART.[103] I accounted for age and sex specific background mortality using the World Health Organization (WHO) life tables.[90]

Disability weights, which represented the total disease burden, were assigned to each health state to project disability-adjusted life-years (DALYs) per strategy.[104] The sum of weights over the analytic time horizon reflected the total strategy specific DALYs lost. Monthly disability weights came from Eaton et al.,[105] derived from the global disease burden study.[106] Disability weights varied based on disease stage (asymptomatic, symptomatic and AIDS) and ART status (On ART and Not on ART). I assigned equal disability weights for all ART health states, irrespective of the disease stage, which is also consistent with other mathematical modeling studies.[107–109] Future DALYs were discounted at 3% per annum.

Costs

Economic costs associated with each HIV testing strategy, linkage to care and ART drugs came from published and grey literature. Costs were valued US dollars for comparability with prior studies and inflation-adjusted to 2017 currency year using the GDP deflator.[60] Future costs were discounted at an annual rate of 3%.[60] HIV testing costs varied by strategy based on the setting (community-based vs healthcare facility-based), medical supplies (blood-based test vs oral self-test), personnel, and patient costs (patient time and transport to healthcare facility). Facility-based strategies required patients to visit the healthcare facility and incurred transportation costs and more time associated with the HIV testing process. Community-based strategies reduced patient costs but incurred more costs to reach patients in the communities. Costs considered included medical (HIV test kits, ART drugs and medical supplies), personnel (salaries for the nurse, healthcare facility management and peer educators), capital (healthcare facility site), overhead, patient time and transport to the healthcare facility. Cost data for HIV self-test kits, personnel, overhead, capital, training and medical supplies costs came from the trial[55] and a costing analysis conducted among truck drivers in Kenya.[32] Costs for peer-educators came from the RCT in Uganda that used peer-educators to distribute HIV self-testing kit and coupons to FSWs.[22] Costs associated with delivery of HIV care among patients on Pre-ART and ART came from the ministry of health report on the cost of comprehensive HIV treatment in Kenya.[110] The cost of ART drugs (first line - TDF+3TC (FTC)+EFV; second line AZT+3TC+ATV/r)[111] came from the Médecins Sans Frontieres report on ART prices in low and middle income countries.[112]

Cost-effectiveness analysis

The total cost and DALYs lost per HIV testing strategy over the time horizon were used to calculate the incremental cost, incremental effectiveness (DALYs averted) and the incremental

effectiveness ratio (ICER). The ICER represents the cost of averting a DALY lost for a given HIV testing strategy compared to the next least costly strategy. HIV testing strategies that cost more but have less health benefits (DALYs averted) compared to the next best alternative are strongly dominated (represented as "s_domintaed"). Those with lower cost and lower health benefits compared to the next most costly strategy are considered weakly dominated (represented as "w_dominated"). Performance of strategies was evaluated by comparing the ICER with the willingness pay threshold (3xGDP per capita for Kenya in 2017),[60] where a strategy is considered to be cost-effective when the ICER is less than the willingness to pay threshold. The threshold represents the willingness to pay value for the additional health benefit gained from a strategy compared to other competing interests. I considered lower thresholds (1-3xGDP per capita) to account for differences in affordability across settings[61–64,79] and examine the robustness of our findings considering at lower willingness to pay thresholds. Further, since many factors (e.g., data quality, the comparator, and sub-groups of the target population) can impact the cost-effectiveness of an intervention, using a fixed WTP threshold as the only criteria to guide decision-making may lead to a wrong decision.[61] There is an ongoing debate in literature about the true WTP threshold to determine the cost-effectiveness of a strategy, partly due to the multiple factors that inform decision making. By considering different WTP thresholds, I account for the uncertainty in the WTP threshold.

Sensitivity analysis

I performed deterministic sensitivity analysis to identify parameter inputs that impact the ICER including the initial distribution given limited data on CD4 in undiagnosed high-risk populations in this setting. Given that our target population is hard to reach, I examined the threshold under which the probability of reaching the targeted population may impact the base case findings. I

first assumed equal probability of reaching the targeted in both community- and facility-based strategies and then examined the threshold for the probability of reaching the targeted population where the community-based strategy may not be cost-effective. In the base case analysis, I assumed that truck drivers and FSWs transition into other occupations by age 50 and were considered part of PLHW in non-high-risk populations. Therefore, I assumed that the probability of reaching the targeted population, HIV test uptake and LTFU varied between age <50 and ≥50 years. I relaxed this assumption and considered truck drivers and FSWs to remain as high-risk sub-populations for the entire time horizon.

Model validation

The model was validated by comparing the life expectancy at 30 years for truck drivers and FSWs living with HIV and on ART to overall population of PLWH in Rwanda on ART.[113] Life expectancy for truck drivers and FSWs in a given CD4 strata was estimated by assuming all (100%) the initial cohort in that CD4 strata and projecting life years over the lifetime horizon. The life expectancy increased based on the CD4 strata at the time of HIV diagnosis with truck drivers and FSWs diagnosed at AIDS stage and initiated on treatment having a life expectancy of nearly 20 years compared to 29 years among those diagnosed at asymptomatic early stage. Life expectancy (Figure 5) estimated in the model was comparable to data from the literature except for the cohort that were diagnosed with CD4>500 which had a lower life expectancy than that reported in the literature. However, this could be a result of high LTFU in hard-to-reach populations and delays in linking to care and initiating treatment. The average life expectancy at 30 years in the model for those diagnosed with CD4>500, CD4 >350 – 500, CD4 >200-350, and CD4 ≤200 was 27.9, 27.1, 25.0 and 19.7, respectively which was comparable with that (30.1, 27.3, 25.9 and 19.06) of people living with HIV in the overall population

Results

Base case analysis

In the base case analysis (Table 4 & 5), among both FSWs and truck drivers, the Kit delivery strategy was cost-effective and had the highest cost and life expectancy at 30 years and lowest DALYs lost. The "No testing" strategy had the lowest cost and life expectancy at 30 years and highest DALYs lost. For undiscounted outcomes, total costs ranged from $1,700 to $10,100 and $1,700 to $7,500 in the "No testing" and "Kit delivery" strategies among FSWs and truck drivers, respectively. More DALYs were lost in the "No testing" strategy (45.36 and 45.6) compared to the "Kit delivery" strategy (29.31 and 33.78) among FSWs and truck drivers, respectively. Findings were consistent for the discounted outcomes. Costs ranged from $1,400 to $6,100 and $1,400 to $4,951; and DALYs lost from 21.93 to 12.70, and from 22.11 and 14.77 among FSWs and truck drivers, respectively. The "Kit delivery" strategy was cost-effective with an ICER of $520 and $480 among FSWs and Truck Drivers, respectively. For undiscounted estimates, all strategies were dominated by the "Kit delivery" strategy in FSWs and truck drivers. However discounted estimates, among FSWs, although the ICERs for the provider-initiated testing ($500) and HIVST Choice ($510) strategies were lower than the WTP and comparable to the ICER for the Kit delivery strategy, these strategies had more DALYs lost compared to the Kit delivery strategy.

Sensitivity analysis

Base case results were mainly sensitive to the cost of ART although policy conclusions did not change. Results of the one-way sensitivity analysis were reported in tornado diagrams, Figure 6 and 7 for FSWs and truck drivers, respectively. Given that our target population was hard to reach, I assessed how the probability of being reached would impact the base case results. When

I assumed equal reach between facility- and community-based strategies, the Kit delivery strategy was still cost-effective (ICER = $498/DALY averted) among truck drivers but among FSWs, the HIVST choice strategy was cost-effective (ICER = $516/DALY averted). In addition, I found that when the probability of reach is below 75%, the kit delivery strategy ceases to be cost-effective among FSWs but not truck drivers. Results were also sensitive to the probability of disclosing test results and seeking a confirmatory test. I found that when the probability of discloser is less than 60%, the Referral card strategy is cost-effective (ICER = $520/DALY averted) among FSWs but not in truck drivers. When I considered truck drivers and FSWs to remain as high-risk for the entire time horizon, base case findings didn't change substantially, with HIVST kit delivery remaining cost-effective among both truck drivers and FSWs.

Discussion

HIV testing and counseling remains substantially low in high-risk and hard-to-reach populations, but little is known about cost-effective strategies to improve HIV test uptake in these populations, particularly in Eastern and Southern Africa. I developed a Markov model to examine the cost-effectiveness of six alternative HIV testing strategies in hard-to-reach populations (truck drivers and FSWs). I found that the delivery of HIVST kits to the targeted population in the community using peer-educators is a cost-effective strategy in both truck drivers and FSWs with an ICER of $480 and $520, respectively. The findings were largely robust to parameter variations in sensitivity analysis but delivery of HIVST kits in the community was not cost-effective among FSWs when the probability of reaching the undiagnosed FWSs or disclosing test results was less than 75% and 60%, respectively.

The findings were broadly consistent with the literature although limited evidence exists on cost-effective HIV testing strategies among high-risk and hard-to-reach populations. Previous studies evaluating the cost-effectiveness of HIV testing have largely focused on the general population, and among high-risk populations, few have included FSWs but not truck drivers. Comparable to this study findings, previous work has shown that community-based strategies, including community-based HIV self-testing, were cost-effective compared to facility-based strategies, particularly in high prevalence areas such Eastern and Southern Africa. For example, in Uganda and South Africa, home-based testing was cost-effective compared to facility-based with an ICER of $3.5 per patient tested[114] and $2,960 per HIV infection averted,[115] respectively. Home-based HIV testing was more cost-effective when targeting high HIV prevalence (32%) areas, with linkage to care and ART initiation expanded to individuals with CD4 cell count >350.[115] Although evidence is limited and emerging, HIVST seems to be cost-effective compared to blood-based provider administered HIV testing. For example, community-based HIVST was cost-effective when uptake of HIV testing increased by at least 20% with the cost of HIVST kit less than $3[47] and when more individuals were diagnosed at early stages of the disease and immediately enrolled on ART.[45] one study that included FSWs as part of the sub-populations in the model, found the community-based HIVST to be cost-effective when the prevalence of undiagnosed FSWs was above 5.5% and the cost per patient equal to $5.61.[46]

Hard-to-reach and high-risk populations have high HIV prevalence and a substantial proportion remain undiagnosed until late stages of the disease. With community-based HIV testing[116–118] such as home-based HIV testing, more undiagnosed individuals may be reached. Home-based VCT and mobile HIV testing have substantially higher (83% and 98%) HIV testing uptake compared to facility-based approaches.[119] Further, community-based approaches reach

undiagnosed individuals at earlier stages of the disease, which can potentially avert new HIV infections and reduce mobility and mortality through early linkage to care and initiation of ART. But despite having high HIV test uptake, community-based approaches have low rates (15-35%) of linkage to care[120] although this can improved (97%) with facilitated linkage to care programs.[119] With facilitated linkage to care programs, the Delivery of HIVST kits at truck stops may be cost-effective.

This is the first study to examine the cost-effectiveness of HIV testing strategies including HIV self-testing and the use of peer-educators with a focus on both truck drivers and FSWs. There is strong evidence supporting use of peer-educators to promote HIV prevention, particularly in high-risk and hard-to-reach populations.[92] I found the HIVST kit delivery strategy using peer-educators cost-effective in both truck drivers and FSWs. Peer-educators usually operate in smaller groups and are able to gain access and trust to populations that are hard to reach with the usual standard of care practices. For example, among FSW, the kit delivery strategy overcomes the limitation of provider stigma faced by FSWs when seeking health care services, particularly in countries where sex work is illegal. Truck drivers are hard to reach due to the unique characteristics of their occupation—highly mobile—that may impact utilization of routine health care services. Using peer-educators may be a suitable strategy to reach those that do not routinely visit the health facility. Previous work on truck drivers has shown that even when drivers are aware of HIV testing services at the healthcare facility that is geographically accessible (e.g., roadside wellness clinic along the truck routes), they were not willing to visit to the health facility.[42] The HIVST kit delivery strategy may improve HIV testing uptake within this population through delivery of kits at truck stops. Although community-based strategies such as the HIVST kit delivery tend to have lower rates of linkage to care compared to facility-based

strategies, using peer-educators may also improve linkage to care and ART initiation by motivating those that test positive for HIV to seek medical care. The kit delivery strategy may also be more attractive to payers since it has high rates of HIV test uptake and requires low skilled labor as compared to provider-administered facility-based testing. But there is a potential problem of high turnover which may negatively impact continuity of the strategy when implemented and overall effectiveness and costs incurred in frequent hiring and training.

This study had several limitations: 1) I did not account for HIV prevalence, which impacts the percentage of individuals diagnosed, total strategy costs and DALYs. When the HIV prevalence is high, more individuals are identified, linked to care, and initiated on treatment increases the costs for the strategy through antiretroviral drugs but lowers the DALYs. By not accounting for HIV prevalence, I am unable to determine thresholds at which strategies are cost-effective based on HIV prevalence in the cohort. However, prior evidence shows HIV testing strategies have been consistently cost-effective even in low prevalence settings of less than 1%.[46,121–123] Both truck drivers and FSWs have relatively high HIV prevalence (>10%),[2–7] thus, considering HIV prevalence will not change the study's overall policy conclusions. For example, in one study HIV prevalence was varied from 0.01% to 20% and was found to be cost-effective in all cases.[123] At 0.01% HIV prevalence, the incremental cost-effectiveness ratio was $451 per quality adjusted life years gained, which is much lower than the GDP per-capita threshold for most of low-income countries.[124] In a community-based self-testing study, HIV testing was found to be cost-effective with HIV prevalence of undiagnosed individuals at 3%.[46] Given that HIV prevalence is high among hard-to-reach populations,[125] HIV testing strategies are likely to be cost-effective at all levels of HIV prevalence. 2) Due to data limitations, I did not include viral suppression in the model and assumed that all fractions of the cohort in ART health states achieved viral

suppression. This assumption may have overestimated the benefits of ART by not accounting for those that did not achieve viral suppression. Those on ART were assigned lower disability weights and by including those that haven't achieved viral suppression, I may have increased the effectiveness of the strategy and the incremental effectiveness, and as a result, the ICER may be lower than the true value leading to wrong decision making. However, the ICERs were substantially lower (<$700) than the WTP threshold ($4700) and thus, we do not anticipate would materially impact the final policy recommendation. 3) Some of the HIV testing strategies were only implemented in one sub-population (e.g., FSWs) but I assumed the same level of efficacy applies to both sub-populations (truck drivers and FSWs). For example, HIVST kit delivery, coupon delivery and VCT referral card were implemented among FSWs although I assumed similar effectiveness among truck drivers and the HIVST choice was only implemented among truck drivers. Although both truck drivers and FSWs are hard-to-reach, the efficacy of these strategies may vary given that HIV testing varies based on gender.

Low uptake of HIV testing, particularly for high-risk and hard-to-reach populations significantly impacts achievement of country and global UNIADS targets. Using peer-educators to deliver HIV self-testing kits in the community is a cost-effective strategy to improve HIV test uptake in populations that are hard to reach and at high-risk of acquiring and transmitting HIV. Future studies should account viral suppression and HIV prevalence.

Chapter IV: Cost-Effectiveness of Alternative Strategies to Reduce Loss to Follow-up after Antiretroviral Therapy Initiation among Female Sex Workers in Eastern and Southern Africa

Introduction

Female sex workers (FSWs) living with HIV, particularly in Eastern and Southern Africa, are at high risk of loss to follow up (LTFU) from antiretroviral therapy (ART) programs.[126,127] However, little evidence exists on strategies to reduce LTFU and their cost-effectiveness. Consistent ART is beneficial for reducing HIV-related morbidity and mortality,[128] and preventing onward HIV transmissions when people living with HIV (PLWH) achieve viral suppression.[129] PLWH are considered LTFU if they miss their last three consecutive visits to the health facility and are not classified as either dead or transferred-out to another healthcare facility.[130]

FSWs are disproportionately impacted by HIV with 30 times higher risk of acquiring HIV compared to the general population.[131] In addition, they are hard-to-reach and face unique barriers that impact their engagement in care.[27] For example, FSWs are unlikely to self-identify as sex workers due to fear of societal violence and provider stigmatization, particularly in countries where sex work is illegal,[27] which impacts their willingness to seek routine care and retention in HIV care for those living with HIV.[27] In fact, among those in HIV care and on ART, up to 53% are LTFU after initiation of ART within 36 months,[11–18] compared to 14% reported for the overall population of PLWH.[19] Given that nearly 1 in 5 of new HIV infections in sub-Saharan Africa is attributed to FSWs,[132] retaining them in care and on ART is critical for

improving HIV-related morbidity and mortality among those living with HIV and preventing onward HIV transmissions.

This study examined the cost-effectiveness of strategies to reduce LTFU among FSWs after initiating ART. Studies conducted in overall population of PLWH suggest home ART delivery,[133] home ART delivery with nutrition supplement,[134] tracing patients who miss appointment plus transport reimbursement[135] and offering free medical care for opportunistic infections and lab tests[136] are effective in reducing LTFU. In West Africa, offering free medical care for opportunistic infections, transport reimbursement and breakfast[137] for PLWH was cost-effective with a baseline LTFU ≥18% and risk reduction ≥41%.[137] However, evidence on cost-effective LTFU strategies is limited, and none exists among FSWs or other high-risk and hard-to-reach populations.

To contextualize the contribution of this study, I discuss the evidence on the cost-effectiveness of LTFU strategies in the overall PLWH. Strategies to reduce LTFU have been shown to be cost-effective when the percentage of people living with HIV and on ART that are LTFU from ART programs was at least 12%.[133,137,138] Community support programs such as delivery of ART in the community and supporting adolescents to adhere to treatment in South Africa reduced LTFU by 40% compared to the standard of care (no community-based support) and was cost-effective.[133] One study examined the cost-effectiveness of three hypothetical strategies: 1) Risk Reduction (40%), lower likelihood of disengaging from care, 2) Outreach (60%), patients with missed ART appointments are traced and re-linked to care, and 3) a combination of both Risk Reduction and Outreach strategies.[138] Compared to the standard of care (no intervention), a combination of Risk Reduction and Outreach was a cost-effective with increase in life

expectancy by 5.2 years, 2.4 Quality adjusted life years (QALYs) gained and an incremental cost-effectiveness ratio of $4700/QALY gained.[138] However, these strategies were hypothetical and their efficacy has not been examined in a real world setting. In West Africa, four strategies to reduce LTFU: 1) elimination of ART co-payments; 2) #1 plus treatment costs for opportunistic infections; 3) #2 plus increased training for health workers; and 4) #3 plus reimbursing transportation costs and providing breakfast for patients attending scheduled visits were examined.[137] With a baseline annual LTFU reduction of 40% (from 18% to 11%), and efficacy range (10% to 75%), a given strategy was be cost-effective if it costs between US $22 - $77 per person-year with efficacy of at least 12 - 41%, respectively.[137] These studies provide baseline for examining strategies in other populations such as FSWs at high risk of LTFU but with limited evidence on strategies to prevent LDTU. Further, identifying efficient strategies to reduce LTFU is critical for guiding resource allocation, particularly in the current climate with constraints in international funding for HIV response programs.[28]

Methods

Overview

I used a Markov model to examine costs and disability-adjusted life years (DALYs) lost of six LTFU strategies in a cohort of FSWs living with HIV and receiving ART. The analysis was conducted from a payer perspective with future DALYs lost and costs discounted at 3%.[60] Each health state was assigned a disability weight to reflect the disease burden. Costs were valued in US dollars and inflation-adjusted to 2017 currency year. The primary outcomes were costs, DALYs averted, and incremental cost-effectiveness ratios (ICERs). The ICER was used to assess the relative performance of the strategies, with the cost-effectiveness of a given strategy determined according to a threshold of 3x the GDP per capita for Kenya in 2017 ($4,710),[60]

although lower thresholds were also assessed to account for differences in affordability and willingness to pay across settings.[61–64,79] Uncertainty in inputs was assessed using probabilistic sensitivity analysis.

Strategies

Six alternative strategies (Table 6) were examined: 1) No intervention; 2) Home ART delivery using community-health workers[133]; 3) Home ART delivery using community-health workers plus monthly nutrition supplement[134]; 4) physical and phone-tracing of patients that miss an appointment plus transport refund to the health facility[135]; 5) physical and phone-tracing with free medical care for opportunistic infections[136]; 6) free medical care for opportunistic infections with transport refund to the health facility and free breakfast.[137]

LTFU strategies came from studies conducted among the overall population of PLWH. I assumed that the effectiveness of these interventions is comparable when implemented in a high-risk and hard-to-reach population such as FSWs. I justified this assumption using the case of HIV pre-exposure prophylaxis (PrEP) since PrEP interventions implemented in both the general population and hard-to-reach population have been similar and have shown comparable effectiveness, with overlap in 95% confidence intervals implying effectiveness across the two populations is not statistically different.

I relied on PrEP interventions, versus other interventions at other steps along the HIV care continuum, to justify this assumption for the following reasons: 1) PrEP interventions implemented in the general population are also routinely implemented among hard-to-reach populations, which enables comparison of their efficacy or effectiveness. 2) There is no evidence

that different PrEP interventions are implemented for the general population and hard-to-reach populations. 3) PrEP interventions are implemented over a longer time period (>1 year), require longer-term adherence and compliance to treatment, and report HIV incidence, which can be used as a proxy measure for adherence and patient behavior outcomes. Adherence is a key factor associated with the likelihood of LTFU among people living with HIV.[139] 4) There is no evidence that different interventions are implemented for the general population and hard-to-reach populations at some additional key steps along the HIV care continuum, including linkage and retention in care. Indeed, no evidence exists for any intervention to promote linkage or retention in care among hard-to-reach populations of people living with HIV. Importantly, however, interventions to improve HIV testing uptake—for which there is variation in implementation across populations[10,22,140–143]—were not considered. This is because, these interventions are implemented for a relatively short period of time[22,144] (compared to PrEP interventions),[145,146] potentially at discrete intervals, and may not adequately capture patient behavior (e.g., visiting the clinic regularly for drug refills), in terms of adherence to a longer term prescribed regimen, over a period of time.

I focused in particular on a particular aspect of PrEP: patient behavior. I relied on patient behavior—defined here in terms of adherence to ART or PrEP continuously and over a longer time horizon—to justify the assumption that LTFU reduction strategies are similarly effective among hard-to-reach populations living with HIV and on ART and among the overall population of PLWH since the behavior that results in PrEP adherence parallels similar behaviors required to remain in HIV care. This parallel is particularly relevant in sub-Saharan Africa where people diagnosed with HIV not only take daily medication but must visit the clinic more regularly (monthly or every two months) for drug refills.[147] When examining adherence to PrEP, I found

comparable adherence to PrEP among hard-to-reach populations and the general population for a given intervention. For example, adherence to PrEP among female sex workers in South Africa ranged from 70% at nine months and 95% at eighteen months[13] compared to HIV discordant couples with average adherence of ≥85% within a similar time period,[148] which is within the range for adherence to PrEP in FSWs.[13] Notably, there is precedent in the mathematical modeling literature to assume that intervention efficacy is similar across different populations. For example, Anderson et al. assumed the efficacy of PrEP to be identical not only across different sub-populations, including FSWs, but also for the general population.[149]

While there are differences in the measures of central tendency for PrEP effectiveness among the general population and hard-to-reach populations, PrEP interventions among the general population report comparable effectiveness among hard-to-reach populations, suggesting that they are not statistically different across the two populations. I drew from this evidence to assume that LTFU interventions are as effective in hard-to-reach populations as in the general population.

Model structure

I used the Markov model in paper 2 (Figure 8) of the dissertation but restricted the initial cohort distribution to health states prior to first-line ART. The model projected lifetime economic costs and DALYs lost associated with each strategy in a hypothetical cohort of FSWs on ART, with a mean age of 30 years. Model health states represented HIV disease clinical stages based on CD4 cell count to account for differences in the probability of LFTU across CD4 cell count strata.[150–152] On-ART disease progression (i.e., changes in CD4 count due to ART) is not modeled, given evidence that LTFU is associated with baseline CD4 count at ART initiation; however, disease

progression is modeled in the absence of ART, with differences in the probability of LTFU and death according to disease progresion.[153,154] The initial cohort was followed over a lifetime time horizon with transitions and outcomes updating monthly to reflect the average frequency of visits to the clinic for drug refills in Eastern and Southern African countries.[155–157] To project lifetime DALYs lost and economic costs, each health state was assigned a disability weight and monthly cost with the sum of DALYs and costs over the analytic time horizon to reflect total strategy-specific DALYs lost and costs.[104]

Data

Data for parameter inputs (Table 7) came from the literature. The initial distribution of FSWs on ART came from a cohort study of newly diagnosed HIV individuals in Kenya,[94] although I assessed other distributions in sensitivity analysis given the limited CD4 data in this setting.[158] Probabilities of disease progression and switching to second-line ART came from a prospective study among PLWH in South Africa[83] and a retrospective study on rates of switching to second-line ART in Uganda,[159] respectively. Monthly disability weights came from Eaton et al.,[105] derived from the global disease burden study.[106] I assumed equivalent disability weights for asymptomatic health states (not on ART). Similarly, all health states indicating patients on ART have equal disability weights irrespective of CD4 cell count given the clinical benefits of ART, comparable to other mathematical modeling studies.[107–109]

Data for LTFU came from a retrospective study that examined retention in care among FSWs on ART in sub-Saharan Africa.[14] Data for LTFU risk reduction came from different studies conducted among PLWH and on ART in sub-Saharan Africa: 1) a retrospective study among young adults on ART in South Africa who received community-based ART delivery[133]; 2) a

prospective community-based support program in Rwanda which provided home ART delivery with nutrition support for PLWH and on ART[134]; 3) a retrospective study among PLWH in Eastern Africa who were LTFU and traced to reengage them in HIV care[135]; 4) a prospective study among adults on ART who received free medical care for opportunistic infections and lab tests with a primary care physician and case manager to monitor the patients' health[136]; 5) a mathematical modeling study that examined hypothetical strategies to reduce LTFU including offering free ART plus medical care for opportunistic infections, transport refund and breakfast.[137]

Costs

Economic costs associated with each strategy came from the literature and reflected a payer perspective.[60] Costs were valued and reported in US dollars ($) and adjusted for inflation to 2017 currency year using the GDP deflator.[60] Costs varied based on the strategy including medical (ART drugs, opportunistic infections drugs and laboratory costs); labor (salaries for healthcare workers including community health care workers, non-clinical healthcare facility staff, physician, and lab technician); capital (health facility and equipment), overhead costs and patient transport refund. Data for ART drugs, labor, capital and overhead costs came from the Ministry of Health costing analysis report for treating PLWH in Kenya.[110] The cost of patient transport to the health facility came from a costing analysis report of PLWH in Uganda.[160] Costs associated with community-based ART delivery including training, salaries, management, equipment and overhead came from a retrospective study among young adults on ART in South Africa.[133] The cost for nutrition supplement was estimated at approximately a $1 per day.[161]

Cost-effectiveness Analysis

Performance of alternative strategies to reduce LTFU was determined based on the willingness to pay (WTP) threshold of 1-3xGDP per capita of Kenya in 2017.[60] We used Kenya as a representative country in Eastern and Southern Africa since it has a large number of truck drivers, routes and truck stops where drivers engage with FSWs.[162] The WTP threshold represents a country's willingness to pay for an additional health benefit, measured as DALYs averted in this study. The GDP per-capita is used as a WTP threshold because the health benefit gained from the intervention would increase an individual's productivity which is measured by an increase the GDP per-capita. While I use a 3xGDP per capita threshold, I take in account the ongoing debate regarding the true threshold for evaluating cost-effectiveness. This debate centers on a criticism that the 1-3xGDP per capita threshold is too high for resource-limited settings, given other competing priorities.[61–64,79] To attend to this concern, I also evaluated cost-effectiveness using a more conservative threshold of 1x GDP per capita for Kenya. Although multiple factors are considered in the decision-making process, the WTP threshold provides a monetary value with which to compare alternative strategies. Strategies with higher costs and lower health benefits than the next most costly alternative were considered "strongly dominated;" strategies with a higher ICER than the next most costly non-dominated alternative strategy were eliminated as "weakly dominated" because they provide less health benefit per additional cost unit.

Sensitivity analysis

One-way, multi-way and probabilistic sensitivity analysis were used to assess uncertainty in parameter inputs. In one-way sensitivity analysis I identified the main cost drivers of variation in the ICER, with the results reported using a tornado diagram, which summarizes the range of

ICERs due to variation in unit cost estimates. For multi-way sensitivity analysis, I considered extreme values (lower and upper bound) of parameter inputs to examine the impact of simultaneous variation of parameters given that in a real-world setting multiple values change concurrently. I conducted a probabilistic sensitivity analysis to assess the impact of random variation in parameter inputs on the cost-effectiveness of the strategies. I assumed a beta and gamma distribution for probability and cost variables, respectively. The beta distribution bounds probability between 0-1 and the gamma accounts for skewness of cost data.[163] Ten thousand Monte Carlo simulations were performed with values sampled randomly within the parameter input range, with ICERs calculated for each simulation. Results from simulations were reported using a cost-effectiveness acceptability curve.[66,67] The acceptability curve summarizes the probability a strategy is cost-effective at different WTP thresholds. I accounted for misclassification of LTFU given prior evidence from sub-Saharan Africa suggests that some patients recorded as LTFU had died or transferred to another clinic.[19,130,164–166] I applied a probability weight of 0.43, derived from 1 – proportion LTFU who die (0.208) – proportion LTFU who self-transfer from site (0.359). These estimates were based on evidence among patients in ART programs in sub-Saharan Africa that suggested 20.8% and 35.9% of patients recorded as LTFU had died or self-transferred to another ART clinic.[19] In the base case analysis I assumed that all strategies are implemented over the cohort's lifetime, which may not be the case in the real-world setting since programs are implemented for shorter time periods such as 5 and 10 years. In particular, "ART delivery + nutrition supplement" was the most effective but costly strategy with nutrition supplement contributing a larger (65%) percentage of the cost. In the sensitivity analysis, I examined the cost-effectiveness of the strategies with nutrition supplement only offered for 5 and 10 years. Further, since "ART delivery + nutrition supplement" was not

cost-effective in the base case, I examined the cost of nutrition supplement at which the strategy would be cost-effective if it is offered throughout the cohort's lifetime.

Results

Base case analysis

In the base case analysis (Tables 8 and 9), ART delivery was cost-effective compared to alternative LTFU strategies. Undiscounted costs ranged from $4,664 to $16,292 and DALYs lost from 28.41 to 23.40 in "No Intervention" and "ART delivery + nutrition supplement", respectively; discounted estimates ranged from $2,994 to $10,022 and 11.52 to 9.27, respectively. ART delivery was cost-effective compared to alternative strategies with an ICER of $470 per DALY averted. ART delivery with nutrition supplement had lower DALYs lost (9.27) but cost substantially more compared to the next best alternative, ART delivery ($10,022 vs $5,173). This resulted in an ICER of $5,100 per DALY averted and was not cost-effective at a willingness to pay threshold of $4,710.

Sensitivity analysis

In one-way sensitivity analysis (Figure 9), we compared the impact of individual parameters on the cost-effectiveness of the "ART delivery" strategy compared to "No Intervention". ART drugs had the largest impact on ICER, in particular, second line ART, and the relative reduction in LTFU by the ART delivery. However, regardless of the variation in the ICER, the study conclusions did not change, ART delivery remained cost-effective compared to No intervention. In the multi-way sensitivity analysis (Tables 10 and 11), the ART delivery + Nutrition supplement strategy was cost-effective when lower bound costs were considered while the "Medical care + Transport + Breakfast" strategy was cost-effective for the upper bound costs. I

examined the impacted of adjustment for LTFU misclassification, but the findings (Table 12 and 13) remained consistent with the base case analysis—ART Delivery remained cost-effective compared to the No Intervention strategy, with an ICER of $500 per DALY averted. When I reduced the time frame when the nutrition supplements were offered to 5 and 10 years (supplementary material, Tables S21 and S22), the "ART delivery + Nutrition" supplement was cost-effective in 5 years (ICER = $4,300) but not in 10 years (ICER = $6,880).

Results for the probabilistic sensitivity analysis are shown in the cost-effectiveness acceptability curve (Figure 10). The probability of cost-effectiveness of a given strategy (No Intervention, ART Delivery and ART Delivery + Nutrition Supplement) varied based on the WTP threshold. When the WTP was <$500, No Intervention had the highest probability of cost-effectiveness; $500-$4,600 ART Delivery was more likely to be cost-effective; and >$460 the ART Delivery + Nutrition Supplement had a higher probability of cost-effectiveness. In the cost-effectiveness plane (Figure 11), majority of the data points for incremental costs and incremental effectiveness fall eastern quadrants of the plane, indicating that ART delivery averted DALYs but may also be cost-saving.

Discussion

I used a Markov model to estimate costs and DALYs averted by strategies aimed at reducing LTFU among FSWs living with HIV and on ART in Eastern and Southern Africa. Home ART delivery using community-health workers was cost-effective at a willingness to pay threshold of $ 470 per DALY averted. I estimated 0.98 DALYs could be averted at an additional cost of $ 466. Taking an example of Rwanda with approximately 12,278 FSWs, of which 6,237 (50.8%)

are living with HIV, these per patient estimates would translate to 6,112 DALYs averted at an additional cost of $2.9m.

LTFU remains a major public health problem that negatively impacts the success of ART programs, particularly in low-income settings.[126,167] Previous studies indicate that LTFU from ART programs increases the risk of treatment failure, drug resistance, viral load rebound and mortality.[128,167,168] A number of factors can contribute to LTFU from ART programs including stigma to visit an HIV clinic, failure to remember getting treatment, distance to the health facility, lack of transport to the clinic and being too sick to visit the clinic.[169] These factors are enhanced particularly among vulnerable populations such as FSWs, leading to higher rates of LTFU.[11–18] For example, in Côte d'ivoire, 53% of 376 female and 38 male sex workers were LTFU of within a follow-up period of 36 months.[14] In South African FSWs, 30% were LTFU within 12 months, which is higher than what is reported (8.5%) in general population considering the same time period.[13]

Strategies to reduce LTFU among FSWs living with HIV may cost more than in the overall HIV population. Previous studies have shown that ART programs that work with members of the community to follow up with patients to support them in adherence to treatment, report improved retention in HIV care,[170] but no study has examined the cost-effectiveness of this strategy. In this study, I found ART delivery in the community was cost-effective in reducing LTFU suggesting that reaching to patients in areas where they live and delivering ART drugs could be an efficient way of retaining them on HIV treatment. Using peer-educators may be suitable for reach the FSWs since some may not be easily identified by community health workers in the general population and this may require me resources. A substantially body of literature has shown

tracing (at home or by phone) patients that miss appointments at the clinic effective in reducing LTFU[171] however, I didn't find tracing cost-effective in this study. This may potentially result from higher costs of tracing a hard-to-reach population such as female sex workers. The costs of tracing FSWs may be higher given that majority are less likely to disclose their physical address for tracing, particularly in countries where sex work is illegal.

ART delivery + nutrition supplement (nutrition offered over a lifetime period) was the most effective strategy but not cost-effective at a willingness to pay threshold of 3xGPD per capita of Kenya ($4,710). Previous work has shown that the nutrition supplement may improve adherence to treatment, retention in HIV care and reduce the mortality rate among patients on HIV treatment since ART drugs affect their metabolism and good nutrition is vital is reducing the side effects of the drugs.[172] In this study, if the reduction in mortality rate was considered, the ART delivery + nutrition supplement strategy may have been more effective with lower total number of DALYs lost over the time horizon and potentially be cost-effective. Previous work found that nutrition supplement was cost-effective when targeting HIV patients who start ART with low body mass index and mulnarished.[173] In sensitivity analysis, I found that offering nutrition supplement for 5 years and reducing the amount of money from $30 to $15 per month would result in ART delivery with nutrition supplement being cost-effective. This suggests that nutrition supplement is a potentially cost-effective intervention when offered for a shorter time period and targeting patients with food insecurity. Although nutrition supplement may be effective in reducing LTFU and improving overall health of PLWH, there may be potential unintended consequences such as FSWs getting HIV so that they can benefit from the nutrition program.[174]

The findings are novel yet comparable to the limited evidence on cost-effectiveness of LTFU strategies in the overall population of PLWH.[133,137,138] In South Africa, a community-based ART support program for adolescents living with HIV was implemented for 2 years and reduced LTFU by 40% compared to the standard of care (no community-based support) and was cost-effective with an incremental cost-effectiveness ratio of US $600 per averted patient LTFU.[133] Adolescents also require targets strategies since to engage in care and the findings[133] support this study conclusion that delivering ART in the communities is a cost-effective approach. In côte d'ivoire, an intervention that offered free ART drugs, treatment costs for opportunistic infections, increased training for health workers, reimbursing transportation costs and provided breakfast for patients attending scheduled visits was found to be cost-effective in reducing LTFU when costs ranged between $22 and $77 per person-year with efficacy of at least 12% to 41%.[137] Although I did not examine this identical strategy, offering free medical care, transport reimbursement and breakfast was not a cost-effective strategy compared to alternative strategies.

This study has several limitations. First, strategies to reduce LTFU that were examined in this study came from previous work done in PLWH on ART in the overall HIV population, which is not representative of a hard-to-reach population. However, despite the differences in study populations, these strategies can be applied to hard-to-reach populations given that similar strategies have been implemented in both hard-to-reach and overall HIV population to improve adherence to PrEP and the effectiveness of those strategies was comparable. Second, this study focuses on FSWs in the Eastern and Southern Africa region, but model parameters were largely derived from Kenya, which I use as a case study country. Although Kenya is a good representative of countries in this setting, estimates may not be generalizable to countries such as South Africa where the cost of living and income classification is higher. Nevertheless, the

findings make contribution to this topic and population that is under studied. Third, potential benefits of nutrition supplement were not accounted for such as reduction in mortality rate which could have increase the effectiveness of the ART delivery + nutrition supplement strategy and potentially the cost-effectiveness. Finally, viral suppression was not included in the model due to limitations of data to inform parameter inputs. Thus, I assumed that all patients on ART achieved viral suppression. This assumption may have overestimated the benefits of ART and underestimated the cost-effectiveness thresholds of the strategies. Although we found ART delivery cost-effective at a low WTP threshold, results need to be interpreted with caution due to potential overestimation of the effectiveness of the strategy from this assumption.

To achieve the global goal of ending the HIV epidemic, its critical to reach all PLWH, link, and retain them on ART. Hard-to-reach populations including FSWs remain disproportionately impacted by HIV with high rates of LTFU from ART programs. This study found that delivering ART drugs to FSWs in their homes, places that they frequent, or community centers is a cost-effective strategy to reduce LTFU among FSWs in ART programs in Eastern and Southern Africa. Despite the lack of RCTs or observations studies examining the effectiveness of LTFU strategies in FSWs or similar hard-to-reach populations, these findings provide insights on efficient interventions to be considered by policy makers.

References

1. Lin D, Zhang C-Y, He Z-K, Zhao X-D. How does hard-to-reach status affect antiretroviral therapy adherence in the HIV-infected population? Results from a meta-analysis of observational studies. BMC Public Health. 2019;19(1):1-13. doi:10.1186/s12889-019-7135-0

2. Delany-Moretlwe S, Bello B, Kinross P, et al. HIV prevalence and risk in long-distance truck drivers in South Africa: a national cross-sectional survey. International Journal of STD & AIDS. 2014;25(6):428-438.

3. KMCC. Most at Risk Populations – Long Distance Truck Drivers and HIV / AIDS in Uganda : Synthesis of Information and Evidence to Inform the Response. Synthesis Report.; 2014.

4. J Bwayo J, M Omari A, N Mutere A, et al. Long distance truck-drivers: 1. Prevalence of sexually transmitted diseases (STDs). East African medical journal. 1991;68:425-429.

5. Botão C, Horth RZ, Frank H, et al. Prevalence of HIV and Associated Risk Factors Among Long Distance Truck Drivers in Inchope, Mozambique, 2012. AIDS and Behavior. 2016;20(4):811-820.

6. Rakwar J, Lavreys L, Thompson M Lou, et al. Cofactors for the acquisition of HIV-1 among heterosexual men: Prospective cohort study of trucking company workers in Kenya. AIDS. 1999;13(5):607-614. doi:10.1097/00002030-199904010-00010

7. Kenya Ministry of Health. Kenya AIDS Response Progress Report 2016.; 2016.

8. Lalla-Edward ST, Ncube S, Matthew P, Hankins CA, Venter WDF, Gomez GB. Uptake of health services among truck drivers in South Africa: Analysis of routine data from nine

roadside wellness centres. BMC Health Services Research. 2017;17(1):1-9.

9. Scorgie F, Nakato D, Harper E, et al. “We are despised in the hospitals”: Sex workers’ experiences of accessing health care in four African countries. Culture, Health and Sexuality. 2013;15(4):450-465. doi:10.1080/13691058.2012.763187

10. Tokar A, Broerse JEW, Blanchard J, Roura M. HIV Testing and Counseling Among Female Sex Workers: A Systematic Literature Review. AIDS and Behavior. 2018;22(8):2435-2457. doi:10.1007/s10461-018-2043-3

11. Holland CE, Papworth E, Billong SC, et al. Antiretroviral treatment coverage for men who have sex with men and female sex workers living with HIV in Cameroon. Journal of acquired immune deficiency syndromes (1999). 2015;68 Suppl 2:S232-40. doi:10.1097/QAI.0000000000000443

12. Muth S, Len A, Evans JL, et al. HIV treatment cascade among female entertainment and sex workers in Cambodia: impact of amphetamine use and an HIV prevention program. Addiction science & clinical practice. 2017;12(1):20. doi:10.1186/s13722-017-0085-x

13. Eakle R, Gomez garriel B, Naicker N. HIV pre-exposure prophylaxis and early antiretroviral treatment among female sex workers in South Africa: Results from a prospective observational demonstration project. PLoS Medicine. 2017;14(11):1-17. doi:10.1371/journal.pmed.1002444

14. Vuylsteke B, Semde G, Auld AF, et al. Retention and risk factors for loss to follow-up of female and male sex workers on antiretroviral treatment in Ivory Coast: a retrospective cohort analysis. J Acquir Immune Defic Syndr. 2015;68 Suppl 2:S99-S106. doi:10.1097/qai.0000000000000442

15. Ibiloye O, Decroo T, Eyona N, Eze P, Agada P. Characteristics and early clinical outcomes of key populations attending comprehensive community-based HIV care: Experiences from Nasarawa State, Nigeria. PLoS ONE. 2018;13(12):1-13. doi:10.1371/journal.pone.0209477

16. Chhim S, Chhea C, Sopheab H, et al. Proportion and predictors of loss to follow-up in a longitudinal cohort study of female entertainment and sex workers in Cambodia. International Journal of STD and AIDS. 2018;29(13):1295-1304. doi:10.1177/0956462418779471

17. Lyons CE, Ketende S, Diouf D, et al. Potential impact of integrated stigma mitigation interventions in improving HIV/AIDS service delivery and uptake for key populations in senegal. Journal of Acquired Immune Deficiency Syndromes. 2017;74(Supplement 1):S52-S59. doi:http://dx.doi.org/10.1097/QAI.0000000000001209

18. Januraga PP, Reekie J, Mulyani T, et al. The cascade of HIV care among key populations in Indonesia: a prospective cohort study. The Lancet HIV. 2018;5(10):e560-e568. doi:10.1016/S2352-3018(18)30148-6

19. Haas AD, Zaniewski E, Anderegg N, et al. Retention and mortality on antiretroviral therapy in sub-Saharan Africa: Collaborative analyses of HIV treatment programmes: Collaborative. Journal of the International AIDS Society. 2018;21(2):1-7. doi:10.1002/jia2.25084

20. UNAIDS. Fast-Track Targets: Ending the AIDS Epidemic by 2030.

21. Kelvin EA, George G, Mwai E, et al. Offering self-administered oral HIV testing to truck drivers in Kenya to increase testing: a randomized controlled trial. AIDS Care.

2018;30(1):47-55.

22. Ortblad K, Kibuuka Musoke D, Ngabirano T, et al. Direct provision versus facility collection of HIV self-tests among female sex workers in Uganda: A cluster-randomized controlled health systems trial. PLoS Medicine. 2017;14(11):1-24.

23. Hlongwa M, Mashamba-Thompson T, Makhunga S, Murararaneza C, Hlongwana K. Men's perspectives on HIV self-testing in sub-Saharan Africa: A systematic review and meta-synthesis. BMC Public Health. 2020;20(1):1-13.

24. Hlongwa M, Mashamba-Thompson T, Makhunga S, Hlongwana K. Mapping evidence of intervention strategies to improving men's uptake to HIV testing services in sub-Saharan Africa: A systematic scoping review. BMC Infectious Diseases. 2019;19(1):469.

25. Johnson CC, Kennedy C, Fonner V, et al. Examining the effects of HIV self-Testing compared to standard HIV testing services: A systematic review and meta-Analysis. Journal of the International AIDS Society. 2017;20(1):1-10.

26. Figueroa C, Johnson C, Verster A, Baggaley R. Attitudes and Acceptability on HIV Self-testing Among Key Populations: A Literature Review. AIDS and Behavior. 2015;19(11):1949-1965.

27. Cwikel JG, Lazer T, Press F, Lazer S. Sexually transmissible infections among female sex workers: An international review with an emphasis on hard-to-access populations. Sexual Health. 2008;5(1):9-16. doi:10.1071/SH07024

28. Kates J, Wexler A, Lief E. Donor Government Funding for HIV in Low- and Middle-Income Countries in 2018.; 2019.

29. Lafort Y, Lessitala F, Candrinho B, et al. Barriers to HIV and sexual and reproductive

health care for female sex workers in Tete, Mozambique: Results from a cross-sectional survey and focus group discussions. BMC Public Health. 2016;16(1). doi:10.1186/s12889-016-3305-5

30. UNAIDS data 2019 | UNAIDS. https://www.unaids.org/en/resources/documents/2019/2019-UNAIDS-data. Published 2019. Accessed September 2, 2020.

31. Fast-Track - Ending the AIDS epidemic by 2030 | UNAIDS. https://www.unaids.org/en/resources/documents/2014/JC2686_WAD2014report. Published 2014. Accessed September 2, 2020.

32. George G, Chetty T, Strauss M, et al. Costing analysis of an SMS-based intervention to promote HIV self-testing amongst truckers and sex workers in Kenya. PLoS ONE. 2018;13(7):1-16.

33. Kates J, Wexler A, Lief E. Donor Government Funding for HIV in Low- and Middle-Income Countries in 2019 | KFF. https://www.kff.org/global-health-policy/report/donor-government-funding-for-hiv-in-low-and-middle-income-countries-in-2019/. Accessed September 2, 2020.

34. North Star Alliance. Key figures. Northstar-alliance.org. https://www.northstar-alliance.org/key-figures/. Published 2018. Accessed June 1, 2020.

35. Orubuloye IO, Caldwell P, Caldwell JC. The Role of High-Risk Occupations in the Spread of AIDS: Truck Drivers and Itinerant Market Women in Nigeria. International Family Planning Perspectives. 2006;19(2):43.

36. Morris CN, Ferguson AG. Sexual and treatment-seeking behaviour for sexually

transmitted infection in long-distance transport workers of East Africa. Sexually Transmitted Infections. 2007;83(3):242-245.

37. Makhakhe NF, Lane T, McIntyre J, Struthers H. Sexual transactions between long distance truck drivers and female sex workers in South Africa. Global Health Action. 2017;10(1):1-9.

38. Morris CN, Ferguson AG. Estimation of the sexual transmission of HIV in Kenya and Uganda on the trans-Africa highway: The continuing role for prevention in high risk groups. Sexually Transmitted Infections. 2006;82(5):368-371.

39. KMCC. Most at Risk Populations – Long Distance Truck Drivers and HIV/AIDS in Uganda: Synthesis of Information and Evidence to Inform the Response. https://www.hivsharespace.net/resource/most-risk-populations-long-distance-truck-drivers-and-hivaids-uganda-synthesis-information. Published 2014. Accessed September 2, 2020.

40. Staveteig S, Wang S, Head SK, Bradley SEK, Nybro E, Macro I. Demographic Patterns of HIV Testing Uptake in Sub-Saharan Africa. DHS Comparative Reports No. 30.; 2013. www.measuredhs.com. Accessed September 2, 2020.

41. Kelvin EA, Akasreku B. The Evidence for HIV Self-Testing to Increase HIV Testing Rates and the Implementation Challenges that Remain. Current HIV/AIDS Reports. 2020;17(4):281-289.

42. Kelvin EA, George G, Kinyanjui S, et al. Announcing the availability of oral HIV self-test kits via text message to increase HIV testing among hard-to-reach truckers in Kenya: a randomized controlled trial. BMC Public Health. 2019;19(1):1-7.

43. Indravudh PP, Choko AT, Corbett EL. Scaling up HIV self-testing in sub-Saharan Africa: a review of technology, policy and evidence. Current Opinion in Infectious Diseases. 2018;31(1):14-24.

44. Kelvin EA, George G, Mwai E, et al. A Randomized Controlled Trial to Increase HIV Testing Demand Among Female Sex Workers in Kenya Through Announcing the Availability of HIV Self-testing Via Text Message. AIDS and Behavior. 2018;23(1):116-125.

45. Maheswaran H, Clarke A, Macpherson P, et al. Cost-Effectiveness of Community-based Human Immunodeficiency Virus Self-Testing in Blantyre, Malawi. Clinical Infectious Diseases. 2018;66(8):1211-1221.

46. Cambiano V, Johnson CC, Hatzold K, et al. The impact and cost-effectiveness of community-based HIV self-testing in sub-Saharan Africa: a health economic and modelling analysis. Journal of the International AIDS Society. 2019;22(S1):e25243.

47. Cambiano V, Ford D, Mabugu T, et al. Assessment of the Potential Impact and Cost-effectiveness of Self-Testing for HIV in Low-Income Countries. Journal of Infectious Diseases. 2015;212(4):570-577.

48. Mangenah C, Mwenge L, Sande L, et al. Economic cost analysis of door-to-door community-based distribution of HIV self-test kits in Malawi, Zambia and Zimbabwe. Journal of the International AIDS Society. 2019;22(S1):e25255.

49. Resch S, Ryckman T, Hecht R. Funding AIDS programmes in the era of shared responsibility: An analysis of domestic spending in 12 low-income and middle-income countries. The Lancet Global Health. 2015;3(1):e52-e61.

50. Global Fund. Mitigating the Impact of COVID-19 on Countries Affected by HIV, Tuberculosis and Malaria.; 2020.

51. The World Back. GDP deflator (base year varies by country) | Data. https://data.worldbank.org/indicator/NY.GDP.DEFL.ZS?end=2019&start=1960. Accessed September 2, 2020.

52. The World Bank. GDP per capita, PPP (current international $) | Data. https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD. Accessed September 2, 2020.

53. Xu X, Nardini HKG, Ruger JP. Micro-costing studies in the health and medical literature: Protocol for a systematic review. Systematic Reviews. 2014;3(1):1-7.

54. Clement FM, Ghali WA, Donaldson C. The impact of using different costing methods on the results of an economic evaluation of cardiac care: micro-costing vs gross-costing approaches. Health economics. 2008;1193(07):659-670.

55. Kelvin E, Mwai E, Romo M, et al. Evaluating Oral HIV Self-Testing to Increase HIV Testing Uptake among Truck Drivers in Kenya.; 2017. http://www.3ieimpact.org/media/filer_public/2017/07/19/ie64-truck-drivers-kenya.pdf.

56. Iyer P, Mwai D, N'ganga A. Costing Kenya's Current and Proposed HIV Testing and Counseling Algorithms. The Health Policy Project. https://www.healthpolicyproject.com/index.cfm?ID=publications&get=pubID&pubID=183. Published May 3, 2013. Accessed September 2, 2020.

57. Cherutich P, Farquhar C, Wamuti B, et al. HIV partner services in Kenya: a cost and budget impact analysis study. BMC Health Services Research. 2018;18(1):1-11.

58. Cook RJ, Sackett DL. The number needed to treat: A Clinically useful measure of treatment effect. British Medical Journal. 1995;310(6977):452-454.

59. Glick HA, Doshi JA, Sonnad SS, Polsky D. Economic Evaluation in Clinical Trials. Oxford University Press; 2014.

60. World Health Organization. Making Choices in Health: WHO Guide to Cost-Effectiveness Analysis.; 2003.

61. Bertram MY, Lauer JA, Joncheere K De, et al. Cost – effectiveness thresholds : pros and cons. Bull World Health Organization. 2016;94(July):925-930.

62. Robinson LA, Hammitt JK, Chang AY, Resch S. Understanding and improving the one and three times GDP per capita cost-effectiveness thresholds. Health Policy and Planning. 2017;32(1):141-145.

63. Shillcutt SD, Walker DG, Goodman CA, Mills AJ. Cost-Effectiveness in Low- and Middle-Income Countries: A review of the Debates Sorrounding Decision Rules. Pharmacoeconomics. 2009;27(11):903-917.

64. Leech AA, Kim DD, Cohen JT, Neumann PJ. Use and Misuse of Cost-Effectiveness Analysis Thresholds in Low- and Middle-Income Countries: Trends in Cost-per-DALY Studies. Value in Health. 2018;21(7):759-761.

65. Little RJA. A test of missing completely at random for multivariate data with missing values. Journal of the American Statistical Association. 1988;83(404):1198-1202.

66. Maiwenn J. AI. Cost-effectiveness acceptability curves revisited. PharmacoEconomics. 2013;31(2):93-100.

67. Löthgren M, Zethraeus N. Definnition, Interpretation and Calculation of Cost-

effectiveness Acceptability Curves. Health economics. 2000;630(April):623-630.

68. OraSure Technologies - OraQuick® Self-Test. https://www.orasure.com/products-infectious/products-infectious-oraquick-self-test.asp. Published 2017. Accessed September 2, 2020.

69. Strauss M, George G, Lansdell E, et al. HIV testing preferences among long distance truck drivers in Kenya: a discrete choice experiment. AIDS Care - Psychological and Socio-Medical Aspects of AIDS/HIV. 2018;30(1):72-80.

70. Lalla-Edward ST, Fischer AE, Venter WDF, et al. Cross-sectional study of the health of southern African truck drivers. BMJ Open. 2019;9(10):1-11.

71. Delavande A, Kohler HP. The Impact of HIV Testing on Subjective Expectations and Risky Behavior in Malawi. Demography. 2012;49(3):1011-1036.

72. WHO HIV Policy Adoption and Implementation Status in Countries|Fact Sheet. https://apps.who.int/iris/bitstream/handle/10665/326035/WHO-CDS-HIV-19.20-eng.pdf?ua=1. Published 2019. Accessed September 2, 2020.

73. Stone J, Mukandavire C, Boily MC, et al. Estimating the contribution of key populations towards HIV transmission in South Africa. Journal of the International AIDS Society. 2021;24(1):1-13. doi:10.1002/jia2.25650

74. Lalla-Edward ST, Matthew P, Hankins CA, Venter WDF, Gomez GB. Healthcare for truck drivers: Assessing accessibility and appropriateness of South African Roadside Wellness Centres. Journal of Transport and Health. 2018;8(January):63-72.

75. Great Lakes Iniative on AIDS. Long-Distance Truck Drivers' Perceptions and Behaviors Towards STI/HIV/TB and Existing Health Services in Selected Truck Stops of the Great

Lakes Region: A Situation Assessment.; 2006.

76. Nnko S, Kuringe E, Nyato D, et al. Determinants of access to HIV testing and counselling services among female sex workers in sub-Saharan Africa: A systematic review. BMC Public Health. 2019;19(1):1-12. doi:10.1186/s12889-018-6362-0

77. Wanyenze RK, Musinguzi G, Kiguli J, et al. "when they know that you are a sex worker, you will be the last person to be treated": Perceptions and experiences of female sex workers in accessing HIV services in Uganda. BMC International Health and Human Rights. 2017;17(1):1-11. doi:10.1186/s12914-017-0119-1

78. UNAIDS. Fast- Track Update on Investments Needed in the AIDS Response.; 2016. http://www.unaids.org/en/resources/presscentre/pressreleaseandstatementarchive/2016/april/20160401_PR_fast-track-update.

79. Zelle SG, Vidaurre T, Abugattas JE, et al. Cost-effectiveness analysis of breast cancer control interventions in Peru. PLoS ONE. 2013;8(12). doi:10.1371/journal.pone.0082575

80. Siebert U, Alagoz O, Bayoumi AM, et al. State-transition modeling: A report of the ISPOR-SMDM modeling good research practices task force-3. Medical Decision Making. 2012;32(5):690-700. doi:10.1177/0272989X12455463

81. Kimmel AD, Mujwara D, Pan Z. Policies Needed in HIV Testing and Treatment Continuum for Rwanda to Achieve the 95-95-95 UNAIDS Targets by 2030: A Mathematical Modeling Study.; 2020.

82. Ying R, Sharma M, Celum C, et al. Home HIV testing and counseling for reducing HIV incidence in a generalized epidemic setting: a mathematical modeling analysis. lancent HIV. 2016;3(6):275-282. doi:10.1016/S2352-3018(16)30009-1

83. Smith JA, Sharma M, Levin C, et al. Cost-effectiveness of community-based strategies to strengthen the continuum of HIV care in rural South Africa: A health economic modelling analysis. The Lancet HIV. 2015;2(4):e159-e168. doi:10.1016/S2352-3018(15)00016-8

84. Karim SSA. HIV-1 Epidemic Control — Insights from Test-and-Treat Trials. New England Journal of Medicine. 2019;381(3):285-286. doi:10.1056/nejme1906559

85. Kimotho J, Ng'ang'a Z, Nyairo E, et al. Laboratory Evaluation of the Validity of the Current HIV Testing Algorithm in Kenya. American Journal of Internal Medicine. 2015;3(1):23. doi:10.11648/j.ajim.20150301.14

86. Information regarding the OraQuick In-Home HIV Test | FDA. https://www.fda.gov/vaccines-blood-biologics/approved-blood-products/information-regarding-oraquick-home-hiv-test#res. Accessed October 14, 2020.

87. Nkenfou CN, Kembou JE, Temgoua ES, et al. Evaluation of OraQuick® HIV-1/2 as oral rapid test. African Journal of Infectious Diseases. 2013;7(2):27-30. doi:10.4314/ajid.v7i2.2

88. National AIDS & STI Control Program M of HK. Guidelines on Use of Antiretroviral Drugs for Treating and Preventing HIV Infection in Kenya 2018 Edition.; 2018.

89. Badri M, Lawn SD, Wood R. Short-term risk of AIDS or death in people infected with HIV-1 before antiretroviral therapy in South Africa: a longitudinal study. Lancet. 2006;368(9543):1254-1259. doi:10.1016/S0140-6736(06)69117-4

90. World Health Organization (WHO). GHO | By category | Life tables by country - Kenya. https://apps.who.int/gho/data/view.main.60850?lang=en. Published 2015. Accessed October 22, 2020.

91. Fobosi SC, Lalla-Edward ST, Ncube S, et al. Access to and utilisation of healthcare services by sex workers at truck-stop clinics in South Africa: A case study. South African Medical Journal. 2017;107(11):994-999. doi:10.7196/SAMJ.2017.v107i11.12379

92. He J, Wang Y, Du Z, Liao J, He N, Hao Y. Peer education for HIV prevention among high-risk groups: A systematic review and meta-analysis. BMC Infectious Diseases. 2020;20(1). doi:10.1186/s12879-020-05003-9

93. Fleurence RL, Hollenbeak CS. Rates and Probabilities in Economic Modelling Transformation, Translation and Appropriate Application. PharmacoEconomics. 2007;25(1):1-4. papers2://publication/uuid/8850A6C3-6F44-4FA2-B3D9-F04ABC2769DE.

94. Harklerode R, Waruiru W, Humwa F, et al. Epidemiological profile of individuals diagnosed with HIV: results from the preliminary phase of case-based surveillance in Kenya. AIDS care. 2020;32(1):43-49. doi:10.1080/09540121.2019.1612021.Epidemiological

95. Ortblad K, Musoke DK, Ngabirano T, Oldenburg C, Bärnighausen T. Direct Provision versus Facility Collection of HIV Tests: Impacts of Self-Testing among Female Sex Workers in Uganda.; 2018.

96. Fobosi SC, Lalla-Edward ST, Ncube S, et al. Access to and utilisation of healthcare services by sex workers at truck-stop clinics in South Africa: A case study. South African Medical Journal. 2017;107(11):994-999. doi:10.7196/SAMJ.2017.v107i11.12379

97. Sharma M, Barnabas R V., Celum C. Community-based strategies to strengthen men's engagement in the HIV care cascade in sub-Saharan Africa. PLoS Medicine.

2017;14(4):1-13. doi:10.1371/journal.pmed.1002262

98. Deuba K, Sapkota D, Shrestha U, et al. Effectiveness of interventions for changing HIV related risk behaviours among key populations in low-income setting: A Meta-Analysis, 2001–2016. Scientific Reports. 2020;10(1):1-13. doi:10.1038/s41598-020-58767-0

99. Staveteig S, Wang S, Head SK, Bradley SEK, Nybro E. Demographic Patterns of HIV Testing Uptake in Sub-Saharan Africa. Calverton, Maryland, USA:; 2013. http://dhsprogram.com/pubs/pdf/CR30/CR30.pdf.

100. Desai MA, Okal DO, Rose CE, et al. Effect of point-of-care CD4 cell count results on linkage to care and antiretroviral initiation during a home-based HIV testing campaign: a non-blinded, cluster-randomised trial. The Lancet HIV. 2017;4(9):e393-e401. doi:10.1016/S2352-3018(17)30091-7

101. Okoboi S, Lazarus O, Castelnuovo B, et al. Peer distribution of HIV self-test kits to men who have sex with men to identify undiagnosed HIV infection in Uganda: A pilot study. PLoS ONE. 2020;15(1):22-28. doi:10.1371/journal.pone.0227741

102. Tymejczyk O, Brazier E, Yiannoutsos CT, et al. Changes in rapid HIV treatment initiation after national “treat all” policy adoption in 6 sub-Saharan African countries: Regression discontinuity analysis. PLoS medicine. 2019;16(6):e1002822. doi:10.1371/journal.pmed.1002822

103. Reniers G, Slaymaker E, Nakiyingi-Miiro J, et al. Mortality trends in the era of antiretroviral therapy: Evidence from the network for analysing longitudinal population based HIV/AIDS data on Africa (ALPHA). AIDS. 2014;28:S533-S542. doi:10.1097/QAD.0000000000000496

104. World Health Organization. Health Statistics and Information Systems. Metrics: Disability-Adjusted Life Year (DALY). Vol 4.; 2017. http://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/.

105. Eaton JW, Menzies NA, Stover J, et al. Health benefits, costs, and cost-effectiveness of earlier eligibility for adult antiretroviral therapy and expanded treatment coverage: A combined analysis of 12 mathematical models. The Lancet Global Health. 2014;2(1). doi:10.1016/S2214-109X(13)70172-4

106. Salomon JA, Haagsma JA, Davis A, et al. Disability weights for the Global Burden of Disease 2013 study. The Lancet Global Health. 2015;3(11):e712-e723.

107. Chen A, Dowdy DW. Clinical effectiveness and cost-effectiveness of HIV pre-exposure prophylaxis in men who have sex with men: Risk calculators for real-world decision-making. PLoS ONE. 2014;9(10). doi:10.1371/journal.pone.0108742

108. Vassall A, Pickles M, Chandrashekar S, et al. Cost-eff ectiveness of HIV prevention for high-risk groups at scale: An economic evaluation of the avahan programme in south India. The Lancet Global Health. 2014;2(9):e531-e540. doi:10.1016/S2214-109X(14)70277-3

109. Mitchell KM, Lépine A, Terris-Prestholt F, et al. Modelling the impact and cost-effectiveness of combination prevention amongst HIV serodiscordant couples in Nigeria. Aids. 2015;29(15):2035-2044. doi:10.1097/QAD.0000000000000798

110. U.S. Centers for Disease Control and Kenyan Ministry of Health. The Cost of Comprehensive HIV Treatment in Kenya: Report of a Cost Study of HIV Treatment Programs in Kenya. Atlanta, GA (USA) and Nairobi, Kenya; 2013.

111. World Health Organization. Consolidated Guidelines on the Use of Antiretroviral Drugs for Treating and Preventing HIV Infection: Recommendations for a Public Health Approach.; 2016. doi:10.1016/j.jped.2014.04.007

112. Medecins Sans Frontieres. Untangling the Web of Antiretroviral Price Reductions.; 2016.

113. Nsanzimana S, Remera E, Kanters S, et al. Life expectancy among HIV-positive patients in Rwanda: A retrospective observational cohort study. The Lancet Global Health. 2015;3(3):e169-e177. doi:10.1016/S2214-109X(14)70364-X

114. Mulogo EM, Batwala V, Nuwaha F, Aden AS, Baine OS. Cost effectiveness of facility and home based HIV voluntary counseling and testing strategies in rural Uganda. African Health Sciences. 2013;13(2):423-429. doi:10.4314/ahs.v13i2.32

115. Ying R, Sharma M, Celum C, et al. Home testing and counselling to reduce HIV incidence in a generalised epidemic setting: a mathematical modelling analysis. The Lancet HIV. 2016;3(6):e275-e282. doi:10.1016/S2352-3018(16)30009-1

116. Hensen B, Taoka S, Lewis JJ, Weiss HA, Hargreaves J. Systematic review of strategies to increase men's HIV-testing in sub-Saharan Africa. AIDS. 2014;28(14):2133-2145. doi:10.1097/QAD.0000000000000395

117. Parker LA, Jobanputra K, Rusike L, et al. Feasibility and effectiveness of two community-based HIV testing models in rural Swaziland. Tropical Medicine and International Health. 2015;20(7):893-902. doi:10.1111/tmi.12501

118. Bachanas PJ, Rajan JS, Ajose O, et al. Towards Universal Voluntary HIV Testing and Counselling: A Systematic Review and Meta-Analysis of Community-Based Approaches. PLoS Medicine. 2013;10(8):e1001496. doi:10.1371/journal.pmed.1001496

119. Sharma M, Ying R, Tarr G, Barnabas R, Division ID, Hutchinson F. A systematic review and meta-analysis of community and facility-based approaches to address gaps in HIV testing and linkage in sub-Saharan Africa. Nature. 2015;528(7580):S77-S85. doi:10.1038/nature16044.A

120. Genberg BL, Naanyu V, Wachira J, Hogan JW. Linkage to and engagement in HIV care in western Kenya: An observational study using population-based estimates from home-based counseling and testing. lancent HIV. 2015;23(1):1-7. doi:10.1038/jid.2014.371

121. Maheswaran H, Clarke A, MacPherson P, et al. Cost-Effectiveness of Community-based Human Immunodeficiency Virus Self-Testing in Blantyre, Malawi. Clinical Infectious Diseases. 2017;66(8):1211-1221.

122. Castel AD, Choi S, Dor A, et al. Comparing cost-effectiveness of HIV testing strategies: Targeted and routine testing in Washington, DC. PLoS ONE. 2015;10(10):1-11. doi:10.1371/journal.pone.0139605

123. N. I, S. D, C. J, et al. Should HIV testing for all pregnant women continue? Cost-effectiveness of universal antenatal testing compared to focused approaches across high to very low HIV prevalence settings. Journal of the International AIDS Society. 2016;19(1 PG-21212):21212. NS -.

124. The World Bank. New country classifications by income level: 2018-2019. The World Bank Group. https://blogs.worldbank.org/opendata/new-country-classifications-income-level-2018-2019. Published 2019. Accessed October 18, 2018.

125. Dwyer-Lindgren L, Cork MA, Sligar A, et al. Mapping HIV prevalence in sub-Saharan Africa between 2000 and 2017. Nature. 2019;570(7760):189-193. doi:10.1038/s41586-

019-1200-9

126. Keane J, Pharr JR, Buttner MP, Ezeanolue EE. Interventions to Reduce Loss to Follow-up During All Stages of the HIV Care Continuum in Sub-Saharan Africa: A Systematic Review. AIDS and Behavior. 2017;21(6):1745-1754. doi:10.1007/s10461-016-1532-5

127. Fox MP, Rosen S. Patient retention in antiretroviral therapy programs up to three years on treatment in sub-Saharan Africa, 2007-2009: Systematic review. Tropical Medicine and International Health. 2010;15(SUPPL. 1):1-15. doi:10.1111/j.1365-3156.2010.02508.x

128. Brinkhof MWG, Spycher BD, Yiannoutsos C, et al. Adjusting mortality for loss to follow-up: Analysis of five art programmes in sub-saharan africa. PLoS ONE. 2010;5(11):3-8. doi:10.1371/journal.pone.0014149

129. World Health Organization (WHO). Programmatic Update. Antiretroviral Treatment as Prevention (TASP) of HIV and TB.; 2012. doi:WHO/HIV/2012.12

130. Johnson LF, Anderegg N, Zaniewski E, et al. Global variations in mortality in adults after initiating antiretroviral treatment: An updated analysis of the International epidemiology Databases to Evaluate AIDS cohort collaboration. Aids. 2019;33(July):S283-S294. doi:10.1097/QAD.0000000000002358

131. Global HIV & AIDS statistics — 2020 fact sheet | UNAIDS. https://www.unaids.org/en/resources/fact-sheet. Accessed March 31, 2021.

132. Prüss-Ustün A, Wolf J, Driscoll T, Degenhardt L, Neira M, Calleja JMG. HIV Due to Female Sex Work: Regional and Global Estimates. PLoS ONE. 2013;8(5):1-7. doi:10.1371/journal.pone.0063476

133. Fatti G, Jackson D, Goga AE, et al. The effectiveness and cost-effectiveness of

community-based support for adolescents receiving antiretroviral treatment: An operational research study in South Africa. Journal of the International AIDS Society. 2018;21:23-34. doi:10.1002/jia2.25041

134. Franke MF, Kaigamba F, Socci AR, et al. Improved retention associated with community-based accompaniment for antiretroviral therapy delivery in rural Rwanda. Clinical Infectious Diseases. 2013;56(9):1319-1326. doi:10.1093/cid/cis1193

135. Bershetyn A, Odeny TA, Lyamuya R, et al. The causal effect of tracing by peer health workers on return to clinic among patients who were lost to follow-up from antiretroviral therapy in Eastern Africa: A "natural experiment" arising from surveillance of lost patients. Clinical Infectious Diseases. 2017;64(11):1547-1554. doi:10.1093/cid/cix191

136. Messou E, Kouakou M, Gabillard D, et al. Medication possession ratio: Predicting and decreasing loss to follow-up in antiretroviral treatment programs in Côte d'Ivoire. Journal of Acquired Immune Deficiency Syndromes. 2011;57(SUPPL. 1):1-13. doi:10.1097/QAI.0b013e3182208003

137. Losina E, Touré H, Uhler LM, et al. Cost-effectiveness of preventing loss to follow-up in HIV treatment programs: A Côte d'Ivoire appraisal. PLoS Medicine. 2009;6(10). doi:10.1371/journal.pmed.1000173

138. Kessler J, Nucifora K, Lifeng L, Uhler L, Braithwaite S. Impact and cost effectiveness of hypothetical strategies to enhance retention-in-care within HIV treatment programs in East Africa. value Health. 2016;18(8):946-955. doi:110.1016/j.bbi.2017.04.008

139. Mberi MN, Kuonza LR, Dube NM, Nattey C, Manda S, Summers R. Determinants of loss to follow-up in patients on antiretroviral treatment, South Africa, 2004-2012: A cohort

study. BMC Health Services Research. 2015;15(1):1-11. doi:10.1186/s12913-015-0912-2

140. Bassett I V., Regan S, Mbonambi H, et al. Finding HIV in Hard to Reach Populations: Mobile HIV Testing and Geospatial Mapping in Umlazi Township, Durban, South Africa. AIDS and Behavior. 2015;19(10):1888-1895. doi:10.1007/s10461-015-1012-3

141. Dugas M, Bédard E, Batona G, et al. Outreach strategies for the promotion of HIV testing and care: Closing the gap between health services and female sex workers in Benin. Journal of Acquired Immune Deficiency Syndromes. 2015;68:S198-S205. doi:10.1097/QAI.0000000000000463

142. Hensen B, Taoka S, Lewis JJ, Weiss HA, Hargreaves J. Systematic review of strategies to increase men's HIV-testing in sub-Saharan Africa. Aids. 2014;28(14):2133-2145. doi:10.1097/QAD.0000000000000395

143. Bateganya MH, Sileo KM, Wanyenze RK, Kiene SM. Strategies for delivery of HIV test results in population-based HIV seroprevalence surveys: a review of the evidence. Public Health. 2016;135:3-13. doi:10.1016/j.puhe.2016.01.011

144. Chanda MM, Ortblad KF, Mwale M, et al. HIV self-testing among female sex workers in Zambia: A cluster randomized controlled trial. PLoS Medicine. 2017;14(11):1-19. doi:10.1371/journal.pmed.1002442

145. Jiang J, Yang X, Ye L, et al. Pre-exposure prophylaxis for the prevention of HIV infection in high risk populations: A meta-analysis of randomized controlled trials. PLoS ONE. 2014;9(2):1-8. doi:10.1371/journal.pone.0087674

146. Hanscom B, Janes HE, Guarino PD, et al. Brief report: Preventing HIV-1 infection in women using oral preexposure prophylaxis: A meta-analysis of current evidence. Journal

of Acquired Immune Deficiency Syndromes. 2016;73(5):606-608. doi:10.1097/QAI.0000000000001160

147. Shade SB, Osmand T, Luo A, et al. Costs of streamlined HIV care delivery in rural Ugandan and Kenyan clinics in the SEARCH Study. Aids. 2018;32(15):2179-2188. doi:10.1097/QAD.0000000000001958

148. Baeten JM, Heffron R, Kidoguchi L, et al. Integrated Delivery of Antiretroviral Treatment and Pre-exposure Prophylaxis to HIV-1–Serodiscordant Couples: A Prospective Implementation Study in Kenya and Uganda. PLoS Medicine. 2016;13(8):1-17. doi:10.1371/journal.pmed.1002099

149. Anderson SJ, Cherutich P, Kilonzo N, et al. Maximising the effect of combination HIV prevention through prioritisation of the people and places in greatest need: A modelling study. The Lancet. 2014;384(9939):249-256. doi:10.1016/S0140-6736(14)61053-9

150. Clouse K, Pettifor A, Maskew M, et al. Initiating antiretroviral therapy when presenting with higher CD4 cell counts results in reduced loss to follow-up in a resource-limited setting. Aids. 2013;27(4):645-650. doi:10.1097/QAD.0b013e32835c12f9

151. van Cutsem G, Ford N, Hildebrand K, et al. Correcting for mortality among patients lost to follow up on antiretroviral therapy in South Africa: A cohort analysis. PLoS ONE. 2011;6(2). doi:10.1371/journal.pone.0014684

152. Seifu W, Ali W, Meresa B. Predictors of loss to follow up among adult clients attending antiretroviral treatment at Karamara general hospital, Jigjiga town, Eastern Ethiopia, 2015: A retrospective cohort study. BMC Infectious Diseases. 2018;18(1):1-8. doi:10.1186/s12879-018-3188-4

153. Cohen MS, Chen YQ, McCauley M, Gamble T, Hosseinipour MC. Prevention of HIV-1 Infection with Early Antiretroviral Therapy. The New England Journal of Medicine. 2011;365(6):493-505. doi:10.1056/NEJMoa1313731

154. Herout S, Mandorfer M, Breitenecker F, et al. Impact of early initiation of antiretroviral therapy in patients with acute HIV infection in Vienna, Austria. PLoS ONE. 2016;11(4):1-11. doi:10.1371/journal.pone.0152910

155. The AIDS Support Organization (TASO) Uganda. Improving Access to HIV Treatment Services through Community Antiretroviral Distribution Points in Uganda.; 2006.

156. Babigumira JB, Castelnuovo B, Stergachis A, et al. Cost effectiveness of a Pharmacy-only Refill Program in a large Urban HIV/AIDS clinic in Uganda. PLoS ONE. 2011;6(3):1-7. doi:10.1371/journal.pone.0018193

157. Rwanda Ministry of Health. National Guidelines for Prevention and Management of HIV and STIs. Edition 201 6.; 2016.

158. Braunstein SL, Ingabire CM, Geubbels E, et al. High burden of prevalent and recently acquired HIV among female sex workers and female HIV voluntary testing center clients in Kigali, Rwanda. PLoS ONE. 2011;6(9).

159. Ssempijja V, Nakigozi G, Chang L, et al. Rates of switching to second-line antiretroviral therapy and impact of delayed switching on immunologic, virologic, and mortality outcomes among HIV-infected adults with virologic failure in Rakai, Uganda. BMC Infectious Diseases. 2017;17(1):1-10. doi:10.1186/s12879-017-2680-6

160. Moreland S, Namisango E, Paxton A, Powell RA. The Costs of HIV Treatment, Care, and Support Services in Uganda.; 2013.

161. Benzekri NA, Sambou JF, Tamba IT, et al. Nutrition support for HIV-TB co-infected adults in Senegal, West Africa: A randomized pilot implementation study. PLoS ONE. 2019;14(7):1-13. doi:10.1371/journal.pone.0219118

162. Newfarmer RS, Page J, Tarp F. Industries without smokestacks: Industrialization in Africa reconsidered. Industries without Smokestacks: Industrialization in Africa Reconsidered. 2018;(July 2021):1-451. doi:10.1093/oso/9780198821885.001.0001

163. Briggs AH. Handling uncertainty in combined endpoints. Pharmacoecnomics. 2000;17(5):479-500. doi:10.2165/00019053-200017050-00006

164. Brinkhof MWG, Dabis F, Myer L, et al. Early loss of HIV-infected patients on potent antiretroviral therapy programmes in lower-income countries. Bulletin of the World Health Organization. 2008;86(7):559-567. doi:10.2471/BLT.07.044248

165. Nuwagaba-Biribonwoha H, Kiragga AN, Yiannoutsos CT, et al. Adolescent pregnancy at antiretroviral therapy (ART) initiation: a critical barrier to retention on ART. Journal of the International AIDS Society. 2018;21(9):1-9. doi:10.1002/jia2.25178

166. Grimsrud A, Cornell M, Schomaker M, Fox MP. CD4 count at antiretroviral therapy initiation and the risk of loss to follow-up: results from a multicentre cohort study. Journal of Epidemiology and Community Health. 2016;70(6):549-555. doi:10.1136/jech-2015-206629.CD4

167. Chammartin F, Zürcher K, Keiser O, et al. Outcomes of Patients Lost to Follow-up in African Antiretroviral Therapy Programs: Individual Patient Data Meta-analysis. Clinical Infectious Diseases. 2018;67(11):1643-1652. doi:10.1093/cid/ciy347

168. Luebbert J, Tweya H, Phiri S, et al. Virological failure and drug resistance in patients on

antiretroviral therapy after treatment interruption in lilongwe, Malawi. Clinical Infectious Diseases. 2012;55(3):441-448. doi:10.1093/cid/cis438

169. Tweya H, Feldacker C, Estill J, et al. Are They Really Lost? "True" Status and Reasons for Treatment Discontinuation among HIV Infected Patients on Antiretroviral Therapy Considered Lost to Follow Up in Urban Malawi. PLoS ONE. 2013;8(9):1-7. doi:10.1371/journal.pone.0075761

170. Forster M, Bailey C, Brinkhof MWG, et al. Electronic medical record systems, data quality and loss to follow-up: Survey of antiretroviral therapy programmes in resource-limited settings. Bulletin of the World Health Organization. 2008;86(12):939-947. doi:10.2471/BLT.07.049908

171. McMahon JH, Elliott JH, Hong SY, Bertagnolio S, Jordan MR. Effects of Physical Tracing on Estimates of Loss to Follow-Up, Mortality and Retention in Low and Middle Income Country Antiretroviral Therapy Programs: A Systematic Review. PLoS ONE. 2013;8(2). doi:10.1371/journal.pone.0056047

172. Tang AM, Quick T, Chung M, Wanke CA. Nutrition assessment, counseling, and support interventions to improve health-related outcomes in people living with HIV/AIDS: A systematic review of the literature. Journal of Acquired Immune Deficiency Syndromes. 2015;68(0 3):S340-S349. doi:10.1097/QAI.0000000000000521

173. Koethe JR, Marseille E, Giganti MJ, Chi BH, Heimburger D, Stringer JS. Estimating the cost-effectiveness of nutrition supplementation for malnourished, HIV-infected adults starting antiretroviral therapy in a resource-constrained setting. Cost Effectiveness and Resource Allocation. 2014;12(1):1-10. doi:10.1186/1478-7547-12-10

174. Thornton R, Kohler H-P. Conditional Cash Transfers and HIV/AIDS Prevention: Unconditionally Promising? World Bank Economic Review. 2012;26(2):165-190. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3624763/pdf/nihms412728.pdf.

175. UNAIDS. People Aged 50 Years and Older.; 2014.

176. Ngugi AK, Agoi F, Mahoney MR, et al. Utilization of health services in a resourcelimited rural area in Kenya: Prevalence and associated household-level factors. PLoS ONE. 2017;12(2):1-12. doi:10.1371/journal.pone.0172728

177. Napierala S, Desmond NA, Kumwenda MK, et al. HIV self-testing services for female sex workers, Malawi and Zimbabwe. Bulletin of the World Health Organization. 2019;97(11):764-776. doi:10.2471/BLT.18.223560

178. Luseno WK, Wechsberg WM. Correlates of HIV testing among South African women with high sexual and substance-use risk behaviours. AIDS Care - Psychological and Socio-Medical Aspects of AIDS/HIV. 2009;21(2):178-184. doi:10.1080/09540120802017594

179. Aho J, Nguyen VK, Diakité SL, Sow A, Koushik A, Rashed S. High acceptability of HIV voluntary counselling and testing among female sex workers: Impact of individual and social factors. HIV Medicine. 2012;13(3):156-165. doi:10.1111/j.1468-1293.2011.00951.x

180. Negin J, Nemser B, Cumming R, Lelerai E, Amor Y Ben, Pronyk P. HIV attitudes, awareness and testing among older adults in Africa. AIDS and Behavior. 2012;16(1):63-68. doi:10.1007/s10461-011-9994-y

181. Ochako R, Vu L, Peterson K. Insights Into Potential Users and Messaging for HIV Oral

Self-Test Kits in Kenya, 3ie Grantee Final Report. Washington, DC. Vol 3ie.; 2014.

182. Thirumurthy H, Masters SH, Mavedzenge SN, Maman S, Omanga E, Agot K. Promoting male partner HIV testing and safer sexual decision making through secondary distribution of self-tests by HIV-negative female sex workers and women receiving antenatal and post-partum care in Kenya: a cohort study. lancent HIV. 2016;3(6):e266-e274. doi:10.1016/S2352-3018(16)00041-2.Promoting

183. Wekesa P, McLigeyo A, Owuor K, Mwangi J, Nganga E, Masamaro K. Factors associated with 36-month loss to follow-up and mortality outcomes among HIV-infected adults on antiretroviral therapy in Central Kenya. BMC Public Health. 2020;20(1):1-11. doi:10.1186/s12889-020-8426-1

184. Ochieng-Ooko V, Ochieng D, Sidle JE, et al. Influence of gender on loss to follow-up in a large HIV treatment programme in western Kenya. Bulletin of the World Health Organization. 2010;88(9):681-688. doi:10.2471/BLT.09.064329

185. Tweya H, Oboho IK, Gugsa ST, et al. Loss to follow-up before and after initiation of antiretroviral therapy in HIV facilities in Lilongwe, Malawi. PLoS ONE. 2018;13(1):1-12. doi:10.1371/journal.pone.0188488

186. Iyer P, Mwai D, N 'ganga A. Costing Kenya'S Current and Proposed Hiv Testing and Counseling Algorithms. Health Policy Project. 2012;(March). https://www.healthpolicyproject.com/pubs/183_KenyaAlgorithms.pdf.

187. IPSOS Limited. Unearthing Value Proposition for Funeral Insurance 2018.; 2018.

188. Bulterys MA, Oyaro P, Brown E, et al. Costs of Point-of-Care Viral Load Testing for Adults and Children Living with HIV in Kenya. Diagnostics. 2021;11(1):140.

doi:10.3390/diagnostics11010140

Tables and Figures

Paper one

Table 1: Mean costs per patient, by cost component and trial arm, reported in 2017 I$

Cost component	CHIVST (Intervention)*		SOC (Control)†		P-value‡
	Mean	95% CI	Mean	95% CI	
HIV test Kit	10.12	[8.85 – 11.38]	0.00§	[0.00 – 0.00]	<0.001
Medical Supplies	0.25	[0.22 – 0.27]	0.30	[0.27 – 0.33]	<0.001
Labor					
Nurse	2.37	[2.22 – 2.53]	1.64	[1.47 – 1.80]	<0.001
Health facility staff	0.92	[0.86 – 0.99]	0.79	[0.71 – 0.87]	0.037
Training	0.08	[0.07 – 0.08]	0.00	[0.00 – 0.00]	<0.001
Capital costs					
Health facility	1.44	[1.34 – 1.54]	1.24	[1.11 – 1.37]	0.037
Equipment	2.18	[2.04 – 2.31]	0.00	[0.00 – 0.00]	<0.001
Overhead	3.59	[3.35 – 3.83]	3.06	[2.75 – 3.37]	0.037
Cell phone service	12.03	[11.28 – 12.79]	0.00	[0.00 – 0.00]	<0.001
Patient time	2.67	[2.45 – 2.79]	1.81	[1.63 – 1.99]	<0.001
Cost per patient	35.59	[33.08 – 38.09]	8.84	[7.96 – 9.73]	<0.001

Abbreviations: CHIVST=Choice of Self-Administered Oral HIV Testing; SOC = Standard of care

* Participants were offered the choice to test for HIV using 1) the provider-administered HIV testing or 2) self-administered oral HIV-testing under the supervision of a provider. If the truck driver declined the two options, they were offered a third option; 3) self-administered oral HIV-testing outside the clinic (at home) without supervision of a provider.

† Participants were offered on the provider-administered HIV testing.

‡ The p-values are from the Wilcoxon rank sum test for differences in median costs by trial arm.

§ The cost of the SOC HIV test kit was I$0.00 because SOC kits were provided by the Kenyan Ministry of Health at the clinic. However, I consider a scenario where the kits are not subsidized by alternative sources in sensitivity analysis.

Figure 1: One-way sensitivity analysis of unit costs

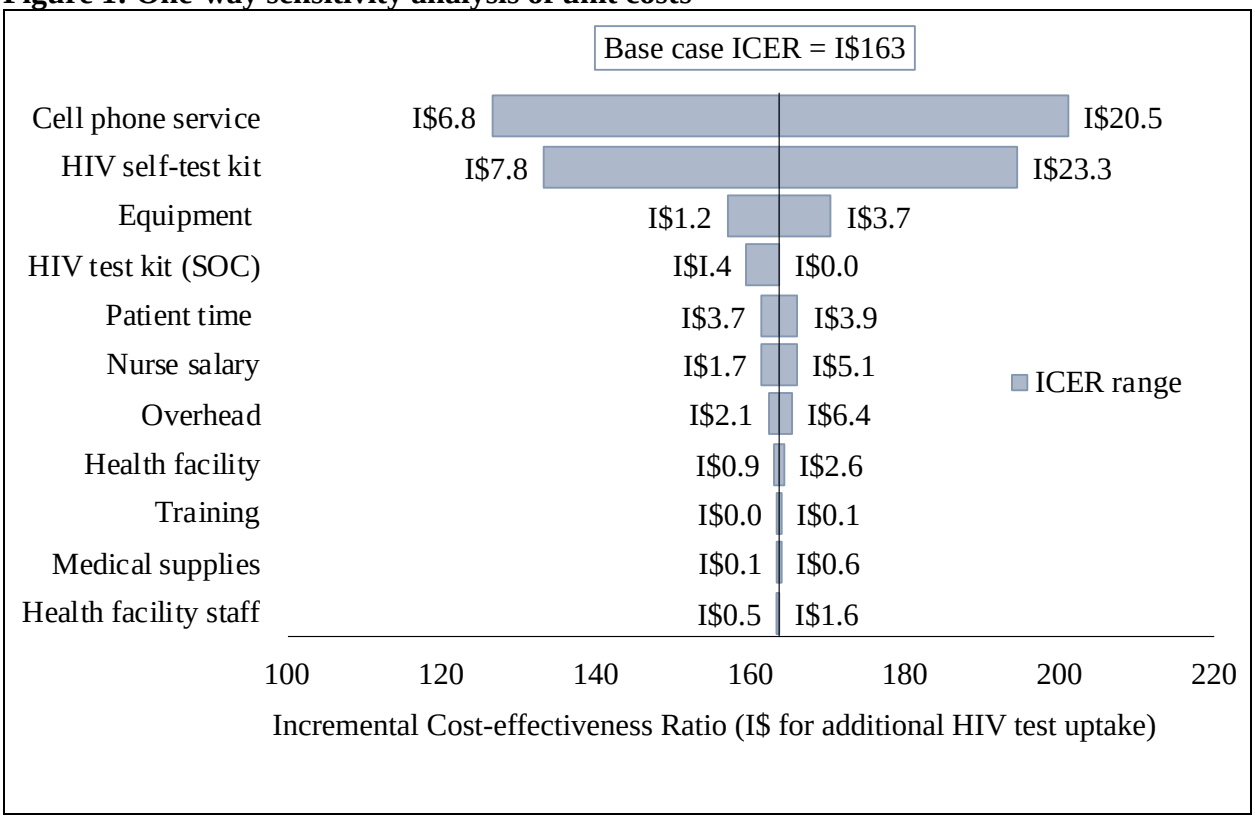
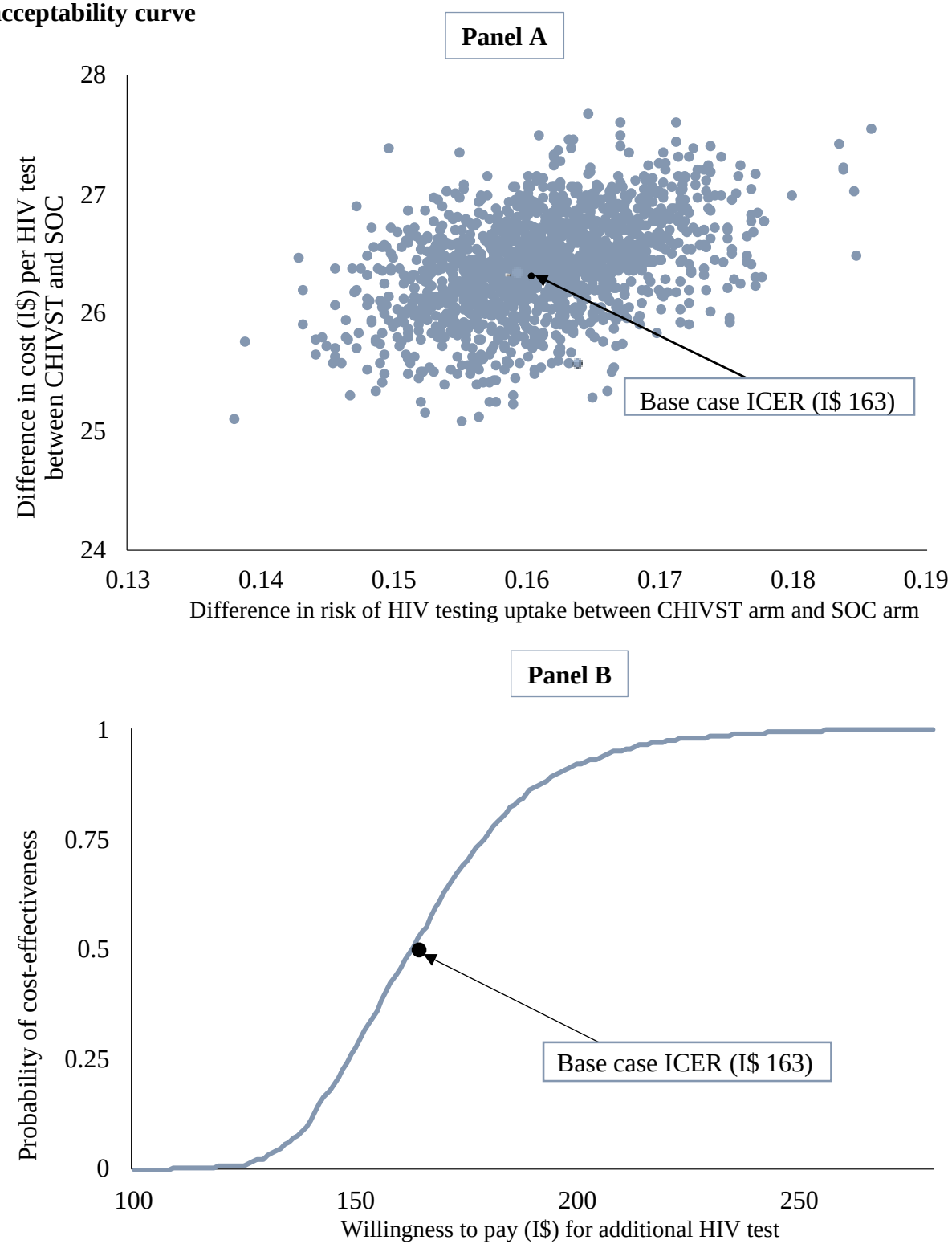


Figure 1 shows the incremental cost-effectiveness ratios (ICERs) corresponding to variations in cost variables based on upper and lower bound values. The x-axis shows the ICER and y-axis the cost variables considered in the study. The vertical line indicates the ICER (I$163) when costs are considered at base line values. The costs of cell phone service and of the HIV self-testing kit were the key drivers of costs and had the largest impact on the ICER followed by equipment (cell phones), and economic cost of the SOC HIV test kit and patient time spent at the clinic for the HIV testing process. Other cost variables have little impact on the ICER.

Figure 2, Panel A shows the joint distribution of the difference in cost (y-axis) and the difference in risk of HIV testing uptake (x-axis) across trial arms from 1500 bootstrap samples. All the data points on the cost-effectiveness plane are in the northeastern quadrant. This implies that offering the CHIVST increases both costs and risk of HIV testing uptake and there is less uncertainty in the cost per additional per HIV test performed since all the data points are clustered in the same quadrant. Panel B shows the probability (y-axis) of CHIVST being cost-effective compared to the SOC is almost equal to 1 when the willingness to pay value (x-axis) is greater than I$ 250. The willingness-to-pay of I$ 250 is much lower than to the cost-effectiveness threshold of I$ 9,774 (3xGDP per capita of Kenya in 2017), which shows that CHIVST is cost-effective compared to the SOC even at very low willingness to pay thresholds. The black dot indicates the base case willingness to pay (I$ 163) with the probability of cost-effectiveness at 0.5.

Figure 2: Joint distribution of difference in cost and effect, and the cost-effectiveness acceptability curve



Paper two

Table 2: HIV testing strategies with associated probability of reaching the target population, test-uptake, and cost per HIV test

		Truck Drivers		Female Sex Workers			
Category*	**Strategy†**	**Reach‡**	**Test uptake**	**Reach‡**	**Test uptake**	**Cost ($ 2017)**	**Source**
	No testing	—	—	—	—	—	
Facility	VCT	0.037	0.022	0.063	0.042	$ 6.77	[29,32,56]
	PITC	0.037	0.103	0.063	0.175	$ 6.77	[21,32,56]
Community	Kit Delivery	0.319	0.198	0.319	0.198	$ 18.73	[22,32,56,95]
Combination	Coupon Delivery	0.319	0.040	0.319	0.115	$ 20.87	[22,32,56,95]
	Referral card	0.319	0.035	0.319	0.093	$ 14.74	[22,32,56,95]
	HIVST Choice	0.037	0.158	0.063	0.221	$ 13.11	[21,32,56]

Abbreviations: HIVST=HIV self-testing; VCT=Voluntary Counseling and Testing; PITC=Provider-initiated counseling and testing

*Strategies are classified based on the setting where the target population was reached and HIV testing. The combination category includes both the health facility and the community setting.

†Strategies are defined as follow: 1) No Testing – I assumed that there is no HIV testing and all FSWs and Truck Drivers living with HIV remained undiagnosed. 2) VCT – FSWs and Truck Drivers voluntarily visit the clinic and request an HIV test which is blood-based and provider-administered. 3) PITC – A health provider at the health facility initiates the discussion with the patient to have an HIV test and when the patient agrees the provider administers the blood-based HIV test. 4) Kit Delivery – HIV self-testing kits are delivered in communities to FSWs and Truck Drivers by peer-educators. 5) Coupon Delivery – HIV self-testing coupons are delivered in the communities to FSWs and Truck Drivers by peer-educators to exchange for a free-of-charge HIV self-test kit at the health facility. 6) – Referral cards are delivered in the community by peer-educators to exchange for a free-of-charge provider-administered blood-based HIV test. 7) HIVST Choice – FSWs and Truck Drivers who visit the clinic to seek care are offered a choice of provider-administered blood-based rapid test OR oral HIV self-testing at the clinic OR, if either testing refused, oral HIV self-testing at home.

‡Reach is defined as the probability of getting in contact with the Truck Drivers and FSWs living with HIV and hard-to-reach.

Table 3: Monthly Parameter Inputs

Parameter*		Baseline (range), [95% CI] Truck drivers	Female sex workers	Source
Initial distribution (%)				94
	Asymptomatic Early	28.8		
	Asymptomatic Late	19.6		
	Symptomatic	19.7		
	AIDS	31.9		
Disease progression				
	Asymptomatic Late	0.013 (0.007 – 0.020)		83
	Symptomatic	0.029 (0.014 – 0.043)		
	AIDS	0.023 (0.012 – 0.035)		
Reaching undiagnosed individuals				74,98,175,176
30-49 years: Non-AIDS stage	Community-based†	0.088 (0.045 – 0.129)	0.088 (0.045 – 0.129)	
	Facility-based‡	0.037 (0.018 – 0.054)	0.063 (0.032 – 0.093)	
30-49 years: AIDS stage	Community-based†	0.129 (0.067 – 0.188)	0.129 (0.067 – 0.188)	
	Facility-based‡	0.054 (0.028 – 0.080)	0.093 (0.047 – 0.135)	
50+ years: Non-AIDS stage		0.319 (0.175 – 0.438)	0.319 (0.175 – 0.438)	
50+ years: AIDS stage		0.438 (0.250 – 0.578)	0.438 (0.250 – 0.578)	
HIV Testing				21,22,29,91,177–180
30-49 years: Non-AIDS stage	HIVST Kit Delivery	0.198 (0.104 – 0.282)	0.198 (0.104 – 0.282)	
	HIVST Coupon Delivery	0.040 (0.020 – 0.059)	0.115 (0.059 – 0.167)	
	VCT Referral card	0.035 (0.017 – 0.052)	0.093 (0.047 – 0.136)	
	HIVST Choice	0.158 (0.082 – 0.227)	0.221 (0.117 – 0.312)	
	PITC	0.103 (0.053 – 0.151)	0.175 (0.091 – 0.250)	
	VCT	0.042 (0.021 – 0.063)	0.022 (0.011 – 0.033)	
30-49 years: AIDS stage	HIVST Kit Delivery	0.282 (0.152 – 0.391)	0.282 (0.152 – 0.391)	
	HIVST Coupon Delivery	0.059 (0.030 – 0.087)	0.167 (0.087 – 0.240)	
	VCT Referral card	0.052 (0.026 – 0.076)	0.136 (0.070 – 0.197)	

	HIVST Choice	0.227 (0.121 – 0.321)	0.312 (0.171 – 0.430)	
	PITC	0.151 (0.078 – 0.217)	0.250 (0.134 – 0.351)	
	VCT	0.063 (0.032 – 0.093)	0.033 (0.017 – 0.049)	
50+ years: Non-AIDS stage		0.019 (0.009 – 0.028)	0.010 (0.005 – 0.015)	
50+ years: AIDS stage		0.028 (0.014 – 0.042)	0.015 (0.008 – 0.023)	
HIV Test Sensitivity (%)				85–87
Initial Test	OraQuick	92.00 [66.00 – 99.00]		
	KHB colloidal Gold	100.00 (97.40 – 100.00)		
Confirmatory test	First Response 1-2.0	100.00 (97.40 – 100.00)		
Tie-breaker test	Uni-Gold	96.40 [91.8 – 98.8]		
Receive confirmatory test				
	Community-based†	0.900 (0.750 – 1.00)		21,181,182
	Facility-based‡	1.000 (0.500 – 1.000)		Assumption
Linkage to care				
	Non-AIDS	0.641 (0.401 – 0.785)		22
	AIDS	0.785 (0.536 – 0.900)		
ART initiation				102
	Non-AIDS	0.830 (0.588 – 0.930)		
	AIDS	0.930 (0.735 – 0.981)		
Switch to second Line ART				
	Non-AIDS	0.004 (0.003 – 0.006)		159
	AIDS	0.006 (0.005 – 0.008)		
Loss to follow up (LTFU)				14,183–185
Pre-ART				
30-49 years	Asymptomatic	0.029 (0.015 – 0.044)	0.025 (0.012 – 0.037)	
	Symptomatic	0.040 (0.020 – 0.059)	0.033 (0.017 – 0.049)	
	AIDS	0.043 (0.022 – 0.059)	0.036 (0.018 – 0.054)	
50+ years		0.025 (0.012 – 0.037)	0.022 (0.011 – 0.033)	
On ART				
30-49 years	Asymptomatic	0.015 (0.007 – 0.022)	0.012 (0.006 – 0.018)	
	Symptomatic	0.020 (0.010 – 0.030)	0.017 (0.008 – 0.025)	

	AIDS	0.022 (0.011 – 0.033)	0.018 (0.009 – 0.027)	
50+ years		0.012 (0.006 – 0.019)	0.012 (0.006 – 0.018)	
Disability weights				105,106
Pre-ART and LTFU	Asymptomatic	0.004 (0.002 – 0.007)		
	Symptomatic	0.023 (0.011 – 0.034)		
	AIDS	0.049 (0.024 – 0.073)		
On ART		0.004 (0.002 – 0.007)		
Costs (US$ 2017)				
HIV testing§				
Initial test				32,95,186
	Kit Delivery	18.73 (9.37 – 28.10)		
	Coupon Delivery	20.87 (10.44 – 31.31)		
	Referral card	14.74 (7.37 – 22.12)		
	HIVST Choice	13.11 (6.55 – 19.66)		
	PITC	6.77 (3.39 – 10.16)		
	VCT	6.77(3.39 – 10.16)		
Confirmatory test		6.75 (3.37 – 10.12)		186
Tiebreaker		7.74 (3.87 – 11.62)		186
Pre-ART¶		23.13 (10.80 – 43.33)		110
First-line ART		33.01 (19.24 – 59.03)		110
Second-Line ART		49.02 (23.06 – 82.59)		110
Death¥		1,692.62 (483.61 – 2,901.63)		187

Abbreviations: DALYs = disability adjusted life-years; HIVST = HIV self-testing; VCT = voluntary counseling and testing; PITC = provider-initiated testing and counseling; ART = Antiretroviral therapy

*Parameters reflect monthly probabilities, costs and disability weights unless specified otherwise

†PLWH are reached in the community for HIV testing

‡PLWH are visit the health facility for HIV testing

§Cost is applied per test uptake

¶Costs included are in Appendix

¥Funeral costs incurred by the family

Table 4: Undiscounted base case cost-effectiveness results¶

Domain*	HIV Testing Strategy	Costs ($)	Incremental Cost ($)	DALYs Lost	DALYs Averted	ICER†
Female sex workers						
Health facility	No Testing	$ 1,693		45.36		
	Voluntary testing	$ 2,909		43.07		w_dominated
	Provider-initiated testing	$ 7,101		35.09		w_dominated
Combination	HIVST Choice	$ 7,561		34.09		w_dominated
	HIV testing referral card	$ 9,143		31.18		w_dominated
	HIVST coupon delivery	$ 9,192		31.10		w_dominated
Community	HIVST kit delivery	$ 10,110	$ 8,418	29.31	16.05	$ 520
Long distance truck drivers						
Health facility	No testing	$ 1,693		45.61		
	Voluntary testing	$ 2,580		43.86		w_dominated
	Provider-initiated testing	$ 3,520		41.99		w_dominated
Combination	HIVST Choice	$ 4,073		40.89		w_dominated
	HIVST coupon delivery	$ 5,021		38.99		w_dominated
	HIV testing referral card	$ 5,123		38.78		w_dominated
Community	HIVST kit delivery	$ 7,549	$ 5,856	33.81	11.80	$ 500

Abbreviations: HIVST = HIV self-testing, DALYs = Disability Adjusted Life Years, ICER = Incremental cost effectiveness ratio; w_dominated = weakly dominated

*Strategies are classified by setting including health facility only, community only and a combination of both the health facility and the community setting.

†ICER is expressed as incremental cost/DALYs averted.

‡Life expectancy at 30 years.

§Compared to "No testing" strategy.

¶Costs and health benefits are undiscounted

Table 5: Discounted base case cost-effectiveness results¶

Domain*	HIV Testing Strategy	Costs ($)	Incremental Cost ($)	DALYs Lost	DALYs Averted	ICER†
Female sex workers						
Health facility	No Testing	$ 1,404		21.93		
	Voluntary testing	$ 2,028		20.70		w_dominated
	Provider-initiated testing	$ 4,301	$ 2,896	16.20	5.73	$ 500
Combination	HIVST Choice	$ 4,565	$ 264	15.69	0.51	$ 510
	HIV testing referral card	$ 5,502		13.88		w_dominated
	HIVST coupon delivery	$ 5,535		13.83		w_dominated
Community	HIVST kit delivery	$ 6,107	$ 1,541	12.70	2.98	$ 520
Long distance truck drivers						
Health facility	No testing	$ 1,425		22.11		
	Voluntary testing	$ 1,911		21.11		w_dominated
	Provider-initiated testing	$ 2,447		19.99		w_dominated
Combination	HIVST Choice	$ 2,769		19.32		w_dominated
	HIVST coupon delivery	$ 3,332		18.18		w_dominated
	HIV testing referral card	$ 3,392		18.04		w_dominated
Community	HIVST kit delivery	$ 4,951	$ 3,526	14.77	7.34	$ 480

Abbreviations: HIVST = HIV self-testing, DALYs = Disability Adjusted Life Years, ICER = Incremental cost effectiveness ratio, w_dominated = weakly dominated

*Strategies are classified by setting including health facility only, community only and a combination of both the health facility and the community setting.

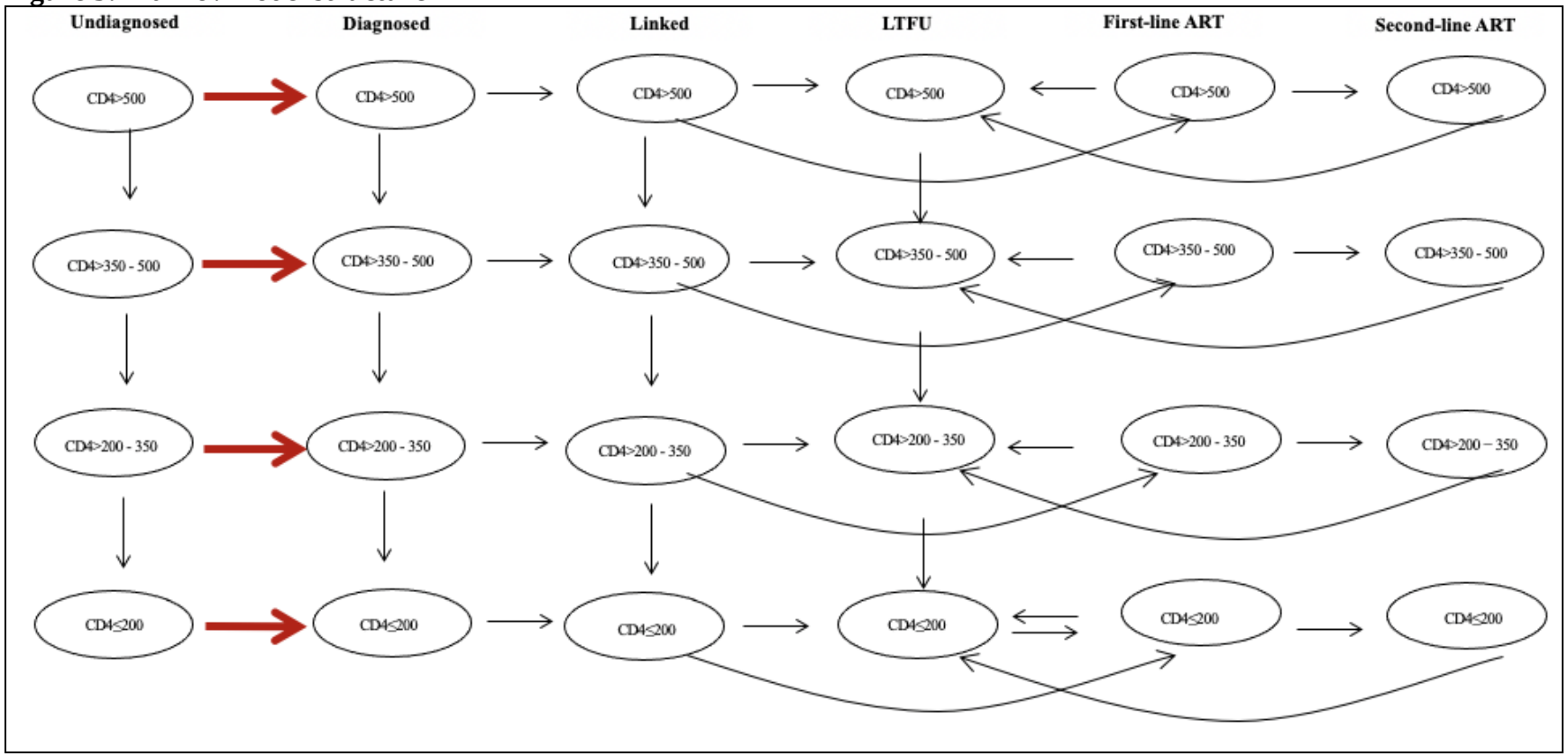
†ICER is expressed as incremental cost/DALYs averted.

‡Life expectancy at 30 years.

§Compared to "No testing" strategy.

¶Costs (2017 $) and health benefits are discounted at 3% per annual.

Figure 3: Markov model structure



Abbreviations: LTFU = Loss to follow up; ART = Antiretroviral therapy

Figure 3 shows the model structure with clinical stages of HIV disease progression defined as follows: Asymptomatic Early (corresponding with CD4 count >500 cells/μL); Asymptomatic Late (corresponding with CD4 count >350 - 500 cells/μL); Symptomatic (CD4 count 200-350 cells/μL); and AIDS (CD4 count 200 cells/μL)). Engagement in HIV care was characterized as undiagnosed, diagnosed, linked to care, on first line ART, on second-line ART, lost from care, and death (not shown). The cohort starts at undiagnosed stages transitions through the health states using probabilities at a monthly cycle. HIV testing strategies impact the probability of being diagnosed.

→ Represents the probability of a FSW or truck driver getting diagnosed and the probability varied across strategies

Figure 4: Schematic for the HIV testing algorithm

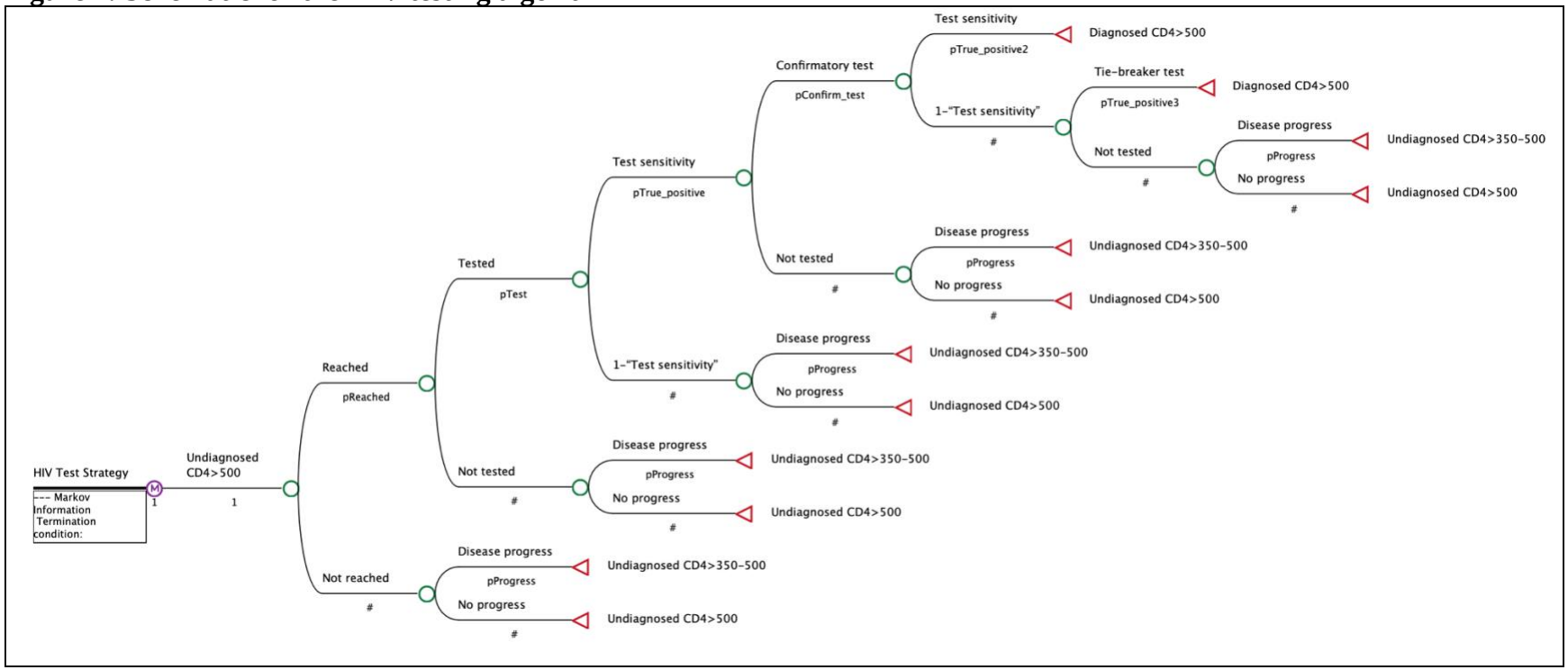


Figure 4 illustrates the possible pathways for HIV testing algorithm used in this study. For example, an initial cohort of undiagnosed truck drivers with CD4>500, a fraction of the cohort can be reached by an HIV testing strategy and among those that are reached, an initial HIV test is offered and if the test is reactive, they perform a confirmatory test or a tiebreaker in a case of inconsistency between the initial test and the confirmatory test. Since all the initial cohort included people living with HIV, fractions of the cohort that are not reached, refused the test, or got a false negative remain undiagnosed.

Figure 5: Model validation with data for the overall population of people living with HIV

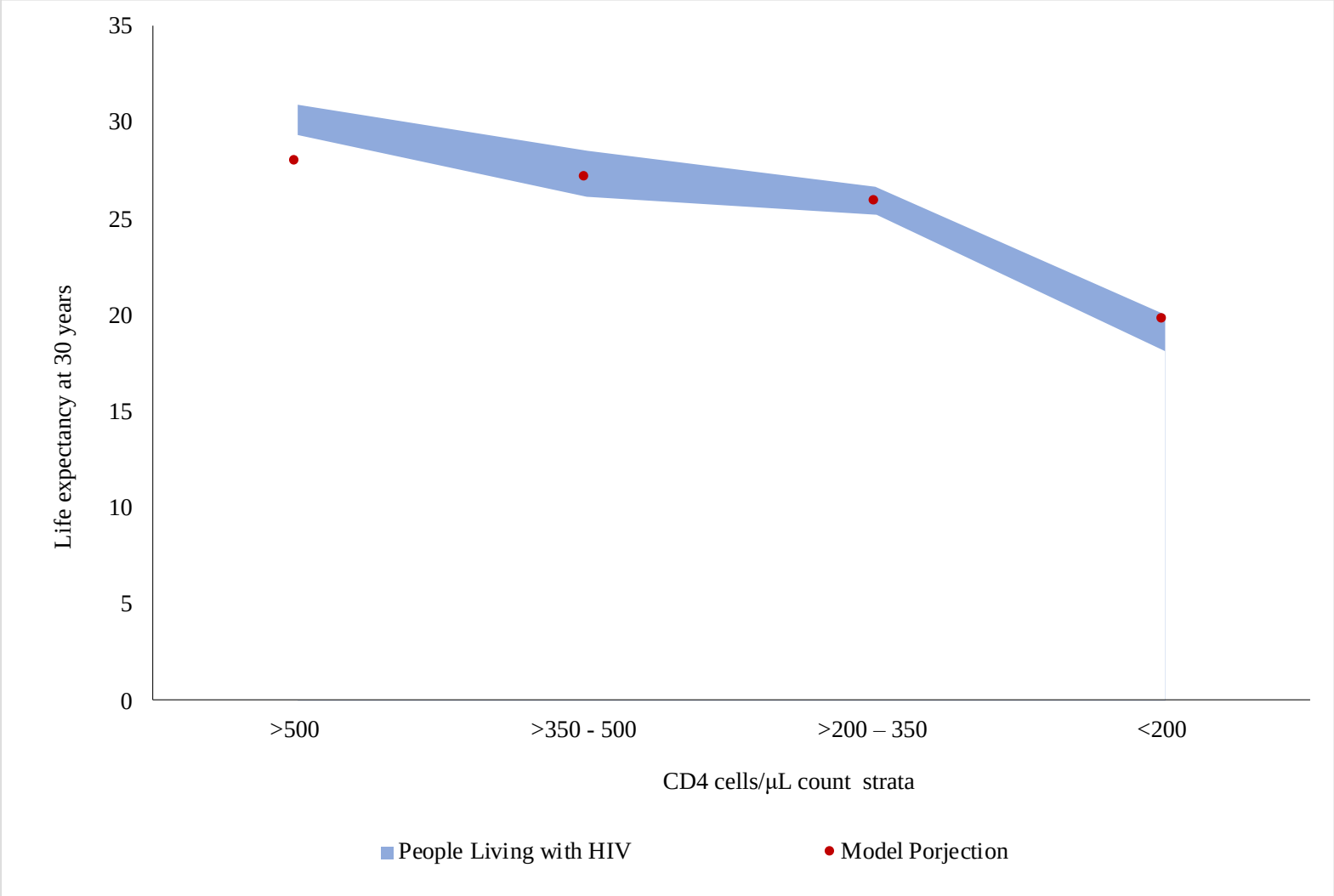
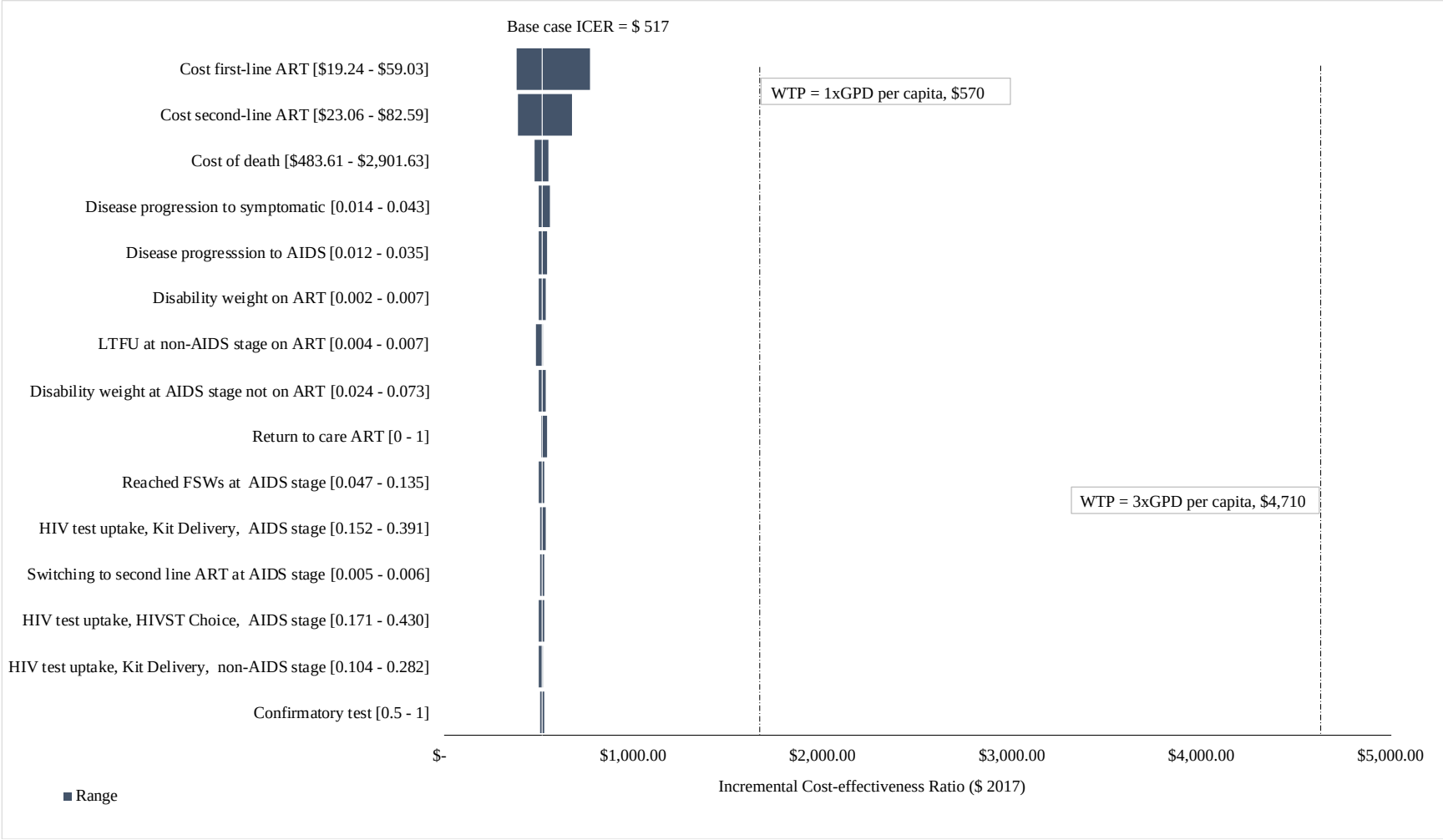


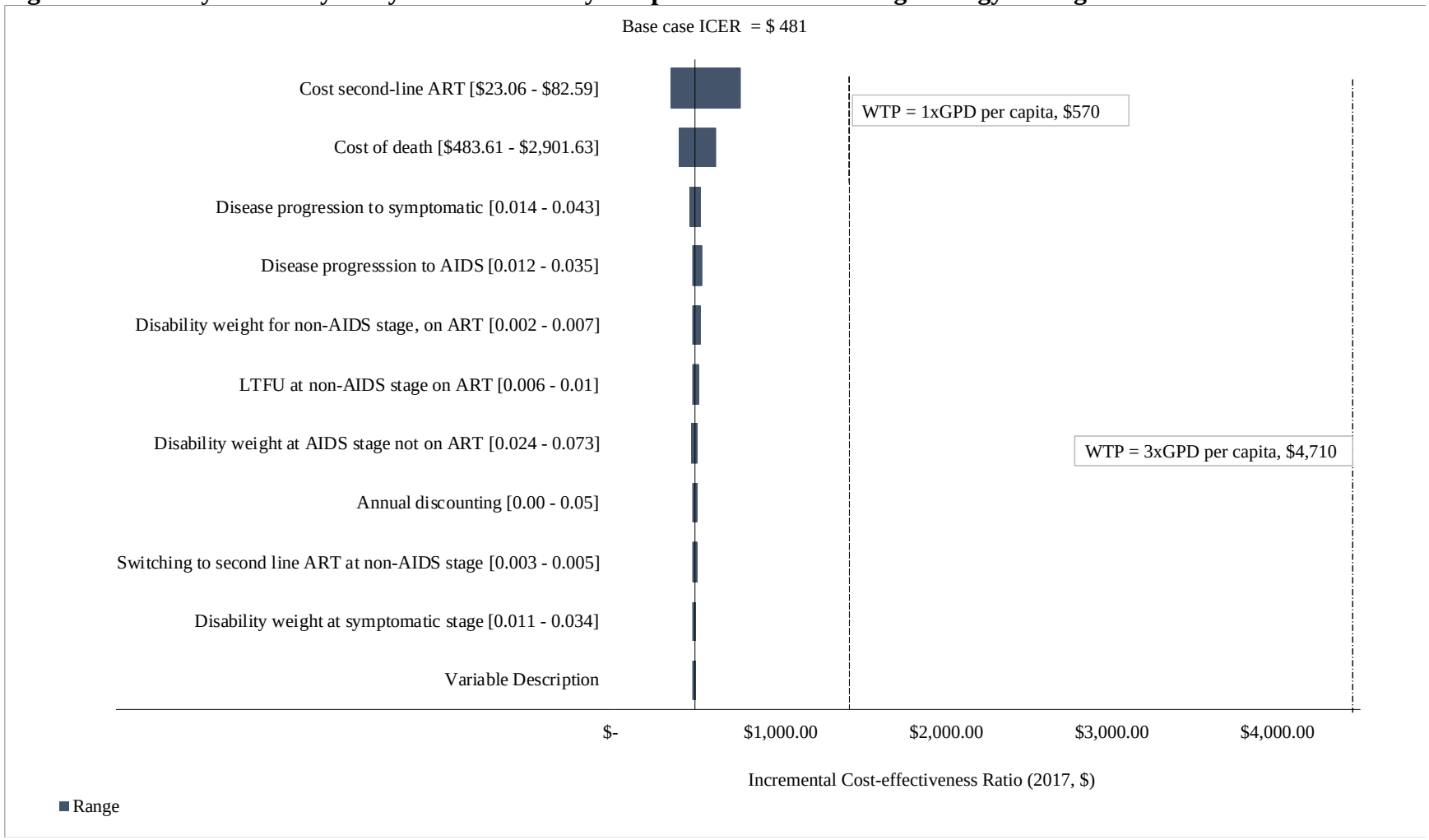
Figure 5 shows results for the model validation. I validated the model by corroborating the life expectancy at 30 years for truck drivers and FSWs living with HIV to data on overall population of PLWH in Rwanda. The blue trend band shows the confidence intervals of life-expectancy for people living with HIV in Rwanda who are diagnosed at 32 years of age.[113] Overall, based on clinical stage at the time of HIV diagnosis, The life expectancy in the model was comparable to the data from Rwanda.

Figure 6: One-way sensitivity analysis of Kit delivery compared to the HIVST Choice among female sex workers



Abbreviations: ART = Antiretroviral Therapy, LTFU = Loss to follow-up, HIVST = HIV self-testing; ICER = Incremental Cost Effectiveness Ratio, WTP = willingness to pay

Figure 7: One-way sensitivity analysis of Kit delivery compared to the No testing strategy among truck drivers



Abbreviations: ART = Antiretroviral Therapy, LTFU = Loss to follow-up, HIVST = HIV self-testing; ICER = Incremental Cost Effectiveness Ratio, WTP = willingness to pay

Paper three

Table 6: LTFU strategies with associated risk reduction and costs

Strategy	Description	LTFU RRR % (range)	Cost, 2017 USD (range)		Source
			First-line ART	Second-line ART	
No Intervention	Standard of care that offers only free ART at the health facility	—	17.38 (8.69 – 26.07)	32.88 (16.44 -49.32)	[14]
ART Delivery	Home free ART delivery by community health workers	40 (29 – 49)	16.62 (8.31 – 24.93)	32.12 (16.06 – 48.18)	[133]
ART Delivery + Nutrition	Home free ART delivery by community health workers plus nutrition supplement	71 (53 – 88)	46.62 (23.31 – 69.93)	62.12 (31.06 – 93.18)	[134]
Tracing + Transport	Free ART, tracing patients that miss appointments with transport reimbursement.	22 (7–36)	24.71 (12.36 – 37.07)	40.21 (20.11 – 60.32)	[135]
Tracing + Medical Care	Free ART, tracing patients that miss appointments with free medical care for opportunistic infections	46 (22 – 63)	26.14 (13.07 – 39.21)	41.64 (20.82 – 62.46)	[136]
Medical Care + Transport + Breakfast	Free ART, treatment for opportunistic infections, transport cost reimbursement, and breakfast.	41 (12 – 75)	23.51 (11.76 – 35.27)	39.01 (19.51 – 58.52)	[137]

Abbreviations: ART = Antiretroviral therapy; RRR = Relative Risk Reduction; LTFU = Loss to follow up

Table 7: Monthly parameter inputs

Parameter*		Baseline (range)	Distribution	Source
Initial distribution, %			Beta	94,158
	Asymptomatic Early	28.8 [41.8]		
	Asymptomatic Late	19.6 [25.3]		
	Symptomatic	19.7 [21.1]		
	AIDS	31.9 [11.6]		
Disease progression			Beta	83
	Asymptomatic Late	0.013 (0.007 – 0.020)		
	Symptomatic	0.029 (0.014 – 0.043)		
	AIDS	0.023 (0.012 – 0.035)		
Switch to second line ART			Beta	159
	Non-AIDS	0.004 (0.003 – 0.006)		
	AIDS	0.006 (0.005 – 0.008)		
LTFU			Beta	
30-49 years: non-AIDS	No Intervention	0.011 (0.008 – 0.013)		14
	ART delivery	0.006 (0.005 – 0.007)		133
	ART delivery + Nutrition	0.003 (0.001 – 0.005)		134
	Tracing + Transport	0.008 (0.007 – 0.010)		135
	Tracing + Medical care	0.006 (0.004 – 0.008)		136
	Medical care + Transport + Breakfast	0.006 (0.003 – 0.009)		137
30-49 years: AIDS	No Intervention	0.021 (0.016 – 0.027)		14
	ART delivery	0.013 (0.011 – 0.015)		133
	ART delivery + Nutrition	0.006 (0.002 – 0.010)		134
	Tracing + Transport	0.016 (0.013 – 0.019)		135
	Tracing + Medical care	0.011 (0.008 – 0.016)		136
	Medical care + Transport + Breakfast	0.012 (0.005 – 0.018)		137
50+ years	No Intervention	0.004 (0.003 – 0.005)		14
	ART delivery	0.002 (0.001 – 0.003)		133
	ART delivery + Nutrition	0.001 (0.001 – 0.002)		134

	Tracing + Transport	0.003 (0.002 – 0.003)		[135]
	Tracing + Medical care	0.002 (0.001 – 0.003)		[136]
	Medical care + Transport + Breakfast	0.002 (0.001 – 0.003)		[137]
Costs (US $, 2017)			Gamma	
FWS on first-line ART	No Intervention	17.38 (8.69 – 26.07)		[110]
	ART delivery	16.62 (8.31 – 24.93)		[110,133]
	ART delivery + Nutrition	46.62 (23.31 – 69.93)		[110,133,161]
	Tracing + Transport	24.71 (12.36 – 37.07)		[110,160]
	Tracing + Medical care	26.14 (13.07 – 39.21)		[110,160,188]
	Medical care + Transport + Breakfast	23.51(11.76 – 35.27)		[110,137,160,188]
FWS on second-line ART	No Intervention	32.88 (16.44 -49.32)		[110]
	ART delivery	32.12 (16.06 – 48.18)		[110,133]
	ART delivery + Nutrition	62.12 (31.06 – 93.18)		[110,133,161]
	Tracing + Transport	40.21(20.11 – 60.32)		[110,160]
	Tracing + Medical care	41.64 (20.82 – 62.46)		[110,160,188]
	Medical care + Transport + Breakfast	39.01 (19.51 – 58.52)		[110,137,160,188]

Abbreviations: ART = Antiretroviral drugs; LTFU = Loss to follow up; FSW = Female sex workers
*Parameters reflect monthly probabilities, costs and disability weights unless specified otherwise

Table 8: Undiscounted base case results for strategies to reduce LTFU from ART programs among female sex workers

Strategy	Cost	Incremental cost	DALYs Lost	DALYs Averted	ICER
No Intervention	$ 4,664.02		28.41		
ART delivery	$ 5,533.25	$ 869.23	26.36	2.05	$ 400
Tracing + Transport	$ 6,842.64		27.44		s_dominated
Medical care + Transport + Breakfast	$ 7,299.20		26.29		w_dominated
Tracing + Medical care	$ 8,218.37		25.92		w_dominated
ART delivery + Nutrition	$ 16,292.13	$ 10,758.88	23.40	2.96	$ 3,200

Abbreviations: LTFU = Lost to follow up; ART = Antiretroviral Therapy; DALYs = Disability Adjusted Life Years; ICER = Incremental cost-effectiveness ratio; w_dominated = weakly dominated; s_dominated = strongly dominated

Table 9: Discounted base case results for strategies to reduce LTFU from ART programs among female sex workers

Strategy	Cost	Incremental cost	DALYs Lost	DALYs Averted	ICER
No Intervention	$ 2,994.56		11.52		
ART delivery	$ 3,460.73	$ 466.17	10.55	0.98	$ 470
Tracing + Transport	$ 4,386.60	--	11.05		s_dominated
Medical care + Transport + Breakfast	$ 4,606.21	--	10.51		w_dominated
Tracing + Medical care	$ 5,173.28	--	10.35		w_dominated
ART delivery + Nutrition	$ 10,022.73	$ 6,561.99	9.27	1.28	$ 5,100

Abbreviations: LTFU = Lost to follow up; ART = Antiretroviral Therapy; DALYs = Disability Adjusted Life Years; ICER = Incremental cost-effectiveness ratio; w_dominated = weakly dominated; s_dominated = strongly dominated

Table 10: Multi-way sensitivity analysis of LTFU strategies with low bound parameter values considered

Strategy	Cost	Incremental cost	DALYs Lost	DALYs Averted	ICER
No Intervention	$ 1,497.28		10.94		
ART delivery	$ 1,632.37	$ 135.00	10.30	0.64	$ 210.00
Tracing + Transport	$ 2,020.06	--	10.70		s. dominated
Medical care + Transport + Breakfast	$ 2,069.35	--	10.80		s. dominated
Tracing + Medical care	$ 2,302.64	--	10.47		s. dominated
ART delivery + Nutrition	$ 4,461.36	$ 2,829.00	9.54	0.76	$ 3,720.00

Abbreviations: LTFU = Lost to follow up; ART = Antiretroviral Therapy; DALYs = Disability Adjusted Life Years; ICER = Incremental cost-effectiveness ratio; w_dominated = weakly dominated; s_dominated = strongly dominated

Table 11: Multi-way sensitivity analysis of LTFU strategies with upper bound parameter values considered

Strategy	Cost	Incremental cost	DALYs Lost	DALYs Averted	ICER
No Intervention	$ 4,491.84		12.23		
ART delivery	$ 5,479.14	$ 987.29	10.94	1.28	$ 770
Tracing + Transport	$ 7,018.73	--	11.37		s. dominated
Medical care + Transport + Breakfast	$ 8,637.60	$ 3,217.41	10.37	1.19	$ 2,670
Tracing + Medical care	$ 8,696.55	--	9.74		s. dominated
ART delivery + Nutrition	$ 17,298.98	$ 8,602.43	8.88	0.86	$ 9,950

Abbreviations: LTFU = Lost to follow up; ART = Antiretroviral Therapy; DALYs = Disability Adjusted Life Years; ICER = Incremental cost-effectiveness ratio; w_dominated = weakly dominated; s_dominated = strongly dominated

Table 12: Undiscounted cost-effectiveness of LTFU strategies after adjusted for misclassification of patients

Strategy	Cost	Incremental cost	DALYs Lost	DALYs Averted	ICER
No Intervention	$ 6,500.45		24.97		
ART delivery	$ 7,431.96	$ 931.51	22.97	2.00	$ 460
Tracing + Transport	$ 9,231.43		23.96		s_dominated
Medical care + Transport + Breakfast	$ 9,625.14		22.91		w_dominated
Tracing + Medical care	$ 10,684.33		22.60		w_dominated
ART delivery + Nutrition	$ 19,338.22	$ 11,906.26	20.80	2.18	$ 5,400

Abbreviations: LTFU = Lost to follow up; ART = Antiretroviral Therapy; DALYs = Disability Adjusted Life Years; ICER = Incremental cost-effectiveness ratio; w_dominated = weakly dominated; s_dominated = strongly dominated

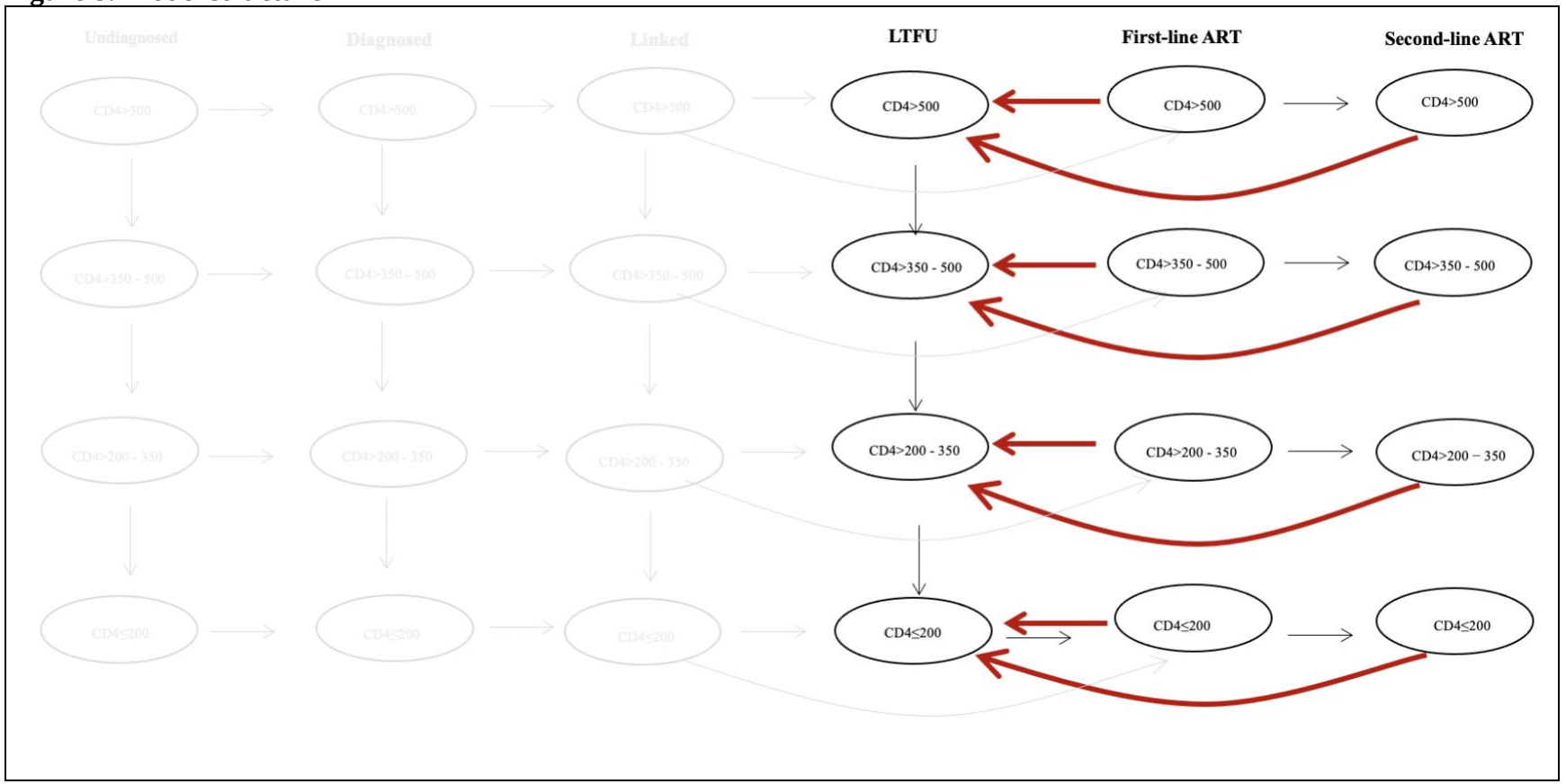
Table 13: Discounted cost-effectiveness of LTFU strategies after adjusted for misclassification of patients

Strategy	Cost	Incremental cost	DALYs Lost	DALYs Averted	ICER
No Intervention	$ 3,987.28		9.93		
ART delivery	$ 4,414.55	$ 427.27	9.09	0.84	$ 500
Tracing + Transport	$ 5,638.55		9.50		s_dominated
Medical care + Transport + Breakfast	$ 5,780.22		9.06		w_dominated
Tracing + Medical care	$ 6,407.93		8.94		w_dominated
ART delivery + Nutrition	$ 11,482.61	$ 7,068.06	8.21	0.88	$ 8,000

Abbreviations: ART = Antiretroviral Therapy; DALYs = Disability Adjusted Life Years; ICER = Incremental cost-effectiveness ratio; w_dominated = weakly dominated; s_dominated = strongly dominated

Tables 12 and 13 show cost-effectiveness results after adjusting for LTFU misclassification. I applied a probability weight of 0.43, derived from 1 – proportion LTFU who die – proportion LTFU who self-transfer from site. In sub-Saharan Africa its estimated that 20.8% and 35.9% of patients recorded as LTFU have died or self-transferred to another ART clinic.[19]

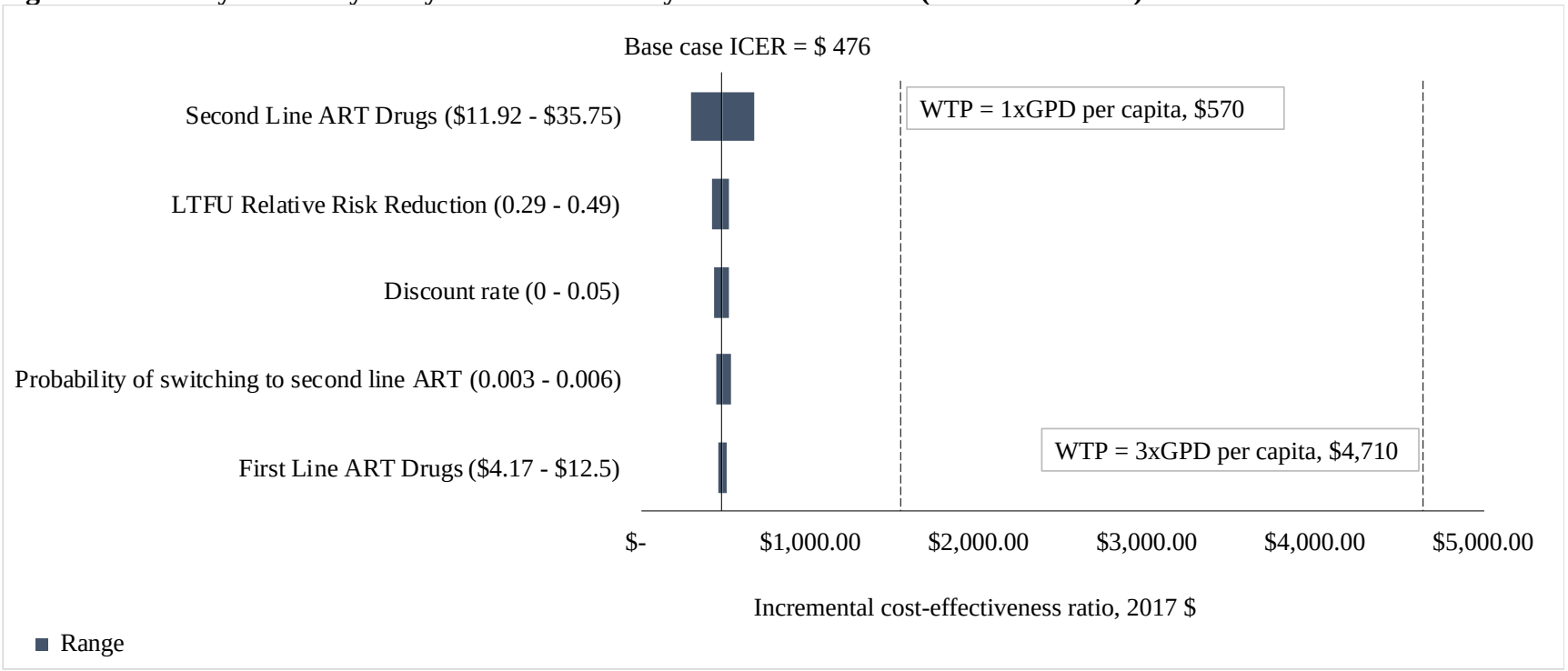
Figure 8: Model structure



Abbreviations: ART = Antiretroviral Therapy; LTFU = Loss to follow up

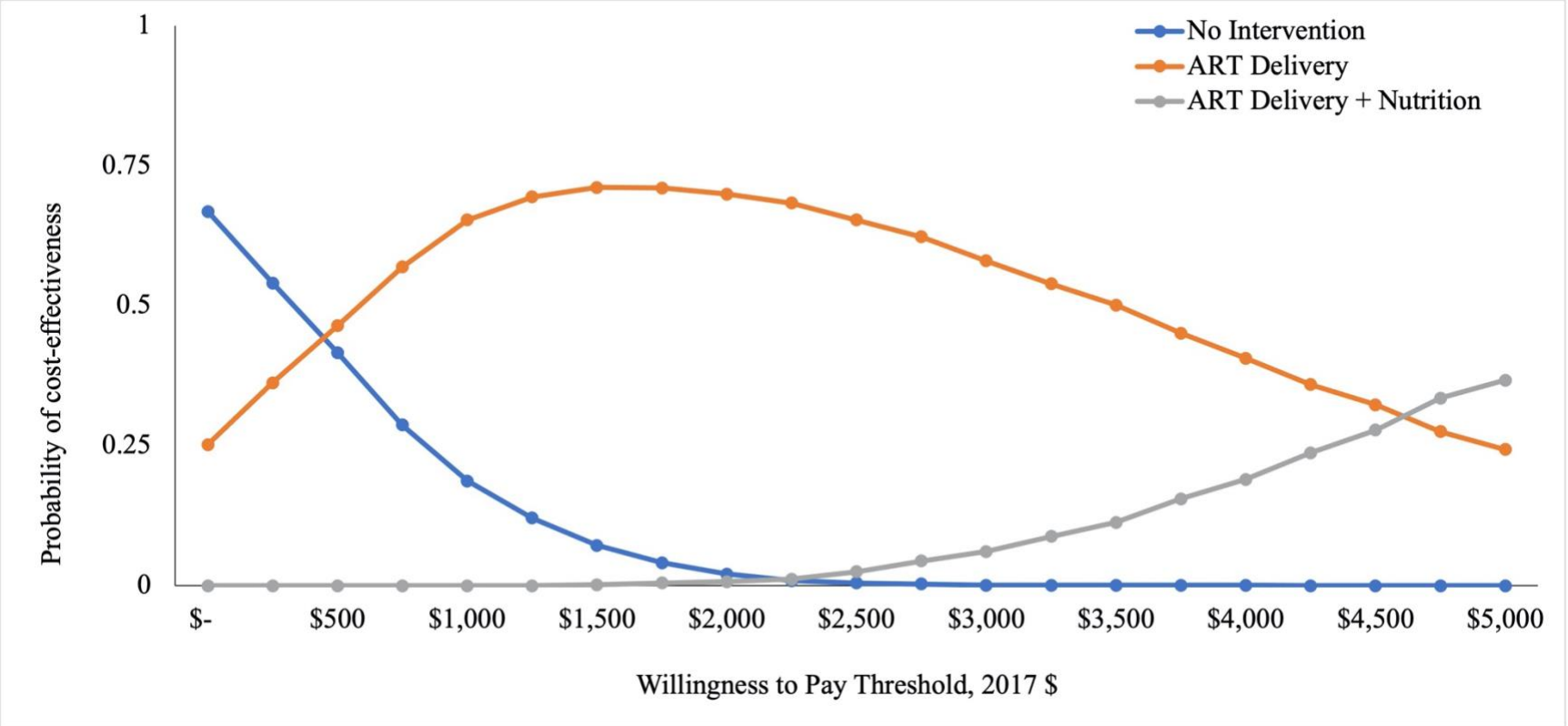
→ Represents the probability of LTFU, which varies across strategies

Figure 9: One-way sensitivity analysis of ART delivery vs No intervention (standard of care)



Abbreviations: ART = Antiretroviral Therapy; LTFU = Loss to follow up; ICER = Incremental Cost-effectiveness Ratio, WTP = willingness to pay

Figure 10: Cost-effectiveness acceptability curves*

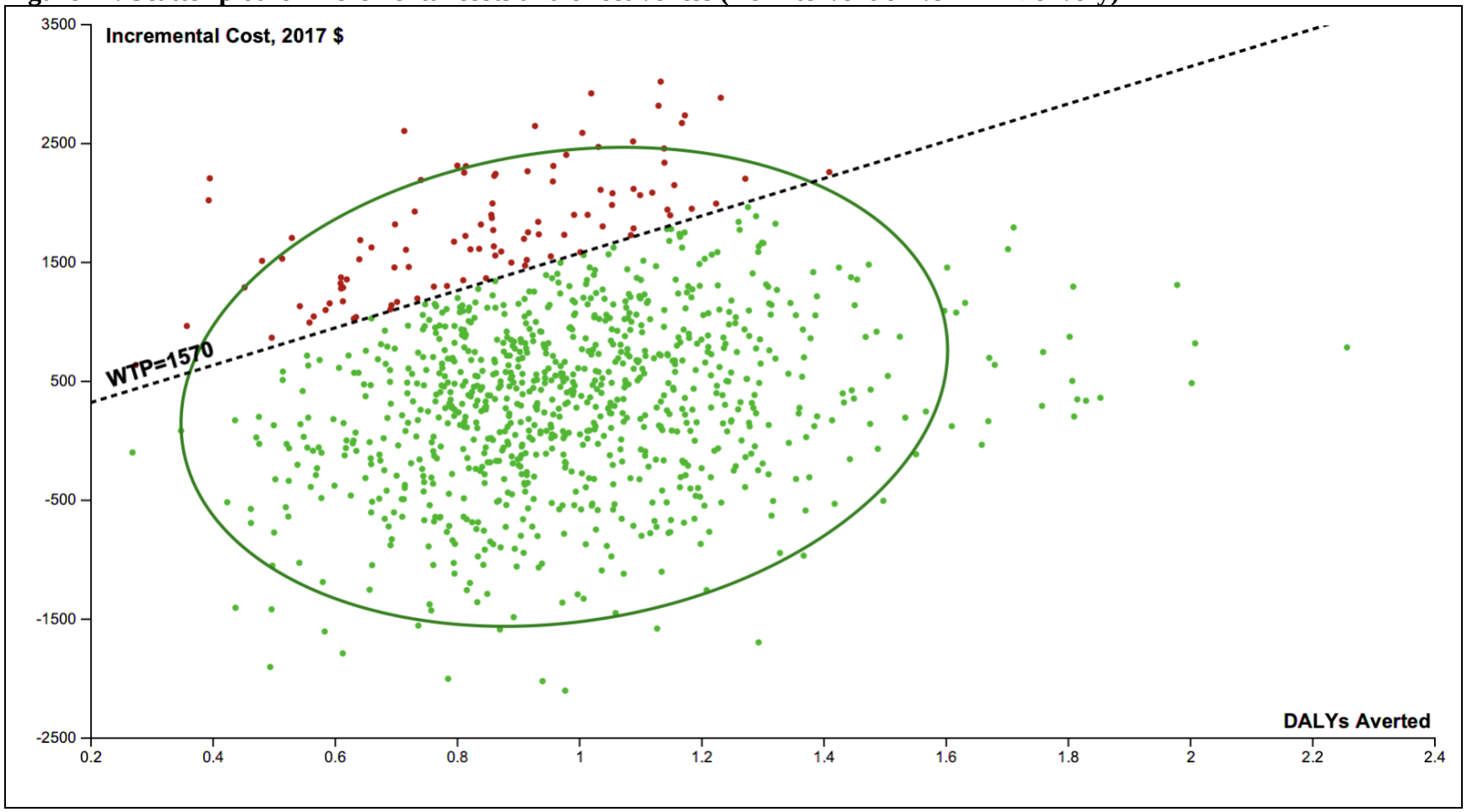


Abbreviations: ART = Antiretroviral Therapy

*Cost-effectiveness acceptability curves of other strategies were not included because their probabilities of cost-effectiveness were always lower than the three strategies indicated in the figure. However, I included the plot in the supplementary material (Figure S6).

Figure 10 shows cost-effectiveness acceptability curve generated from the probabilistic sensitivity analysis. When the WTP was <$500, No Intervention had the highest probability of cost-effectiveness; $500-$4,600 ART Delivery was more likely to be cost-effective; and >$460 the ART Delivery + Nutrition Supplement had a higher probability of cost-effectiveness.

Figure 11: Scatter plot for incremental costs and effectiveness (No Intervention vs ART Delivery)



Abbreviations: ART = Antiretroviral Therapy; DALYs = Disability Adjusted Life Years; WTP = Willingness to Pay

Figure 11 shows the cost-effectiveness plane with majority of the data points for the joint distribution of incremental costs and incremental effectiveness fall in the Northeastern and Southeastern quadrants of the plane, indicating that the ART delivery strategy averted DALYs and may also be cost-saving.

Supplementary material

This document contains supplemental information including the justification for analytical decisions, analyses, and results.

Supplementary materials for paper one

Table S1: Summary of justifications for analytical decisions

Analytical Decision	Recommendation
Study perspective This study was conducted based on a societal perspective	The WHO recommends conducting cost-effectiveness studies from a societal perspective, which takes into account direct health (e.g., clinical services) and non-health (e.g., patient time) related costs of a health intervention for a society as a whole regardless of who is paying.[1]
Inflation adjustment The GDP deflator was used for inflation adjustment because it is the only available and recommended index inflation adjustment in low-income settings such as Kenya. The Gross Domestic Product (GDP) deflator is a price index which measures the annual change in prices for a quantity goods and services produced in the economy including those exported to other countries. The index is more comprehensive as it takes into account government and household consumption and international trade.	The WHO recommends the Gross Domestic Product deflator to be used for inflation adjustment of health sector costs because it takes into account changes in prices in the whole economy.[1]
Currencies used for measuring and reporting costs We reported costs in international dollars to facilitate comparison of cost-effectiveness results across other countries in the region. An international dollar is a hypothetical currency, which has the same value as the US dollar and has the same purchasing power in every country. The international dollar is used in cost-effectiveness analysis because it enables cross-country comparisons of costs easier and interventions easier. The purchasing power of 1 I$ is the same in all countries. Costs reported in local currency are converted to international dollars using the purchasing power parity (PPP) exchange rate, which takes into account the country's standards of living.	The WHO recommends that costs are valued in international dollars to enable comparison of results across countries/settings. For interventions that are specifically local, and all prices are collected in local currency, WHO recommends using the local currency since it is more practical and useful to local policy makers.[1]

Statistical model for estimating effectiveness The Poisson regression model with a robust variance was used to estimate the effectiveness of CHIVST. The Poisson regression model is part of the generalized linear models and uses the log-link function. Poisson regression model with a robust variance has been shown in literature to generate similar results as the log-binomial model.[2] We use a robust variance because the Poisson regression model does not impose any restrictions to the estimated parameter and hence is likely to overestimates the bounds of the estimate.[3]	There is no gold standard statistical model that is recommended for estimating relative risks for cohort studies. However, the log-binomial model is recommended in literature since it generates more reliable confidence intervals. But, given the challenges of convergence of the log-binominal model, the Poisson model with robust-variance is recommended as an alternative model.
Statistical model for estimating incremental costs The generalized linear gamma model was used to estimate the incremental costs. A review on regression models for analyzing cost data found that the gamma GLM is preferred estimating costs.[4] The gamma model does not assume equal variance across datasets and is not affected by skewed distribution of the data.	In literature, there is no consensus on a single model to use for estimating mean costs per trial arm. However, the generalized linear gamma model is commonly recommended because it produces unbiased mean costs.

Table S2: Methods and recommendations for inflation adjustment

Method	Description	Advantages	Disadvantages	Recommendations and Decision	Source
The consumer price index (CPI)	The CPI is a statistical estimate that reflects the change in prices of a fixed basket of consumer goods and services. The goods and services considered for the index are representative of the usual consumer expenditures. The CPI is calculated on a monthly basis and weights are used to generate the aggregated annual CPI. The CPI uses the Laspeyres price index—an arithmetic mean for a fixed basket of goods and services and adjusted periodically to take into account changes in consumption and production of goods and services. The CPI has a medical component, which takes into account differences in prices for medical sector.	1 – Most frequently used method to account for general inflation and easy to understand. 2 – CPI can be generated for specific commodities. For example, the Medical CPI can be computed for only medical costs (drugs, physician, and nurse salaries)	1 – CPI depends only on a fixed basket of consumer goods and services selected, which may not reflect all the health care related costs. For example, CPI takes into account only out-of-pocket but not all medical expenditures. 2 – CPI may not be appropriate if the rate in change of price for a specific resource is not the same as the general price inflation. 3 – The index does not take into account the substitution effect where consumers are more likely to substitute goods and services that are pricy for cheaper goods, hence overestimating the inflation. 4 – The CPI medical component has been reported to have measurement errors but also	WHO: Recommends the Gross Domestic Product deflator to be used for inflation adjustment of health sector costs because it takes into account changes in prices in the whole economy. US Panel: Recommends inflation adjustment to be done using the Personal Health Care expenditure deflator because it accurately reflects the changes in prices in the medical sectors as compared to the Consumer Price Index or Personal Consumption Expenditure. In case the Personal Health Care is not available for the current year, the panel recommends using the Personal Health Care up to the most recent year and then use the Personal	[1,5]

			it is not available in many countries including Kenya.	Consumption Expenditure.[5]	
The Gross Domestic Product (GDP) deflator	The GDP deflator is a price index which measures the annual change in prices for a quantity goods and services produced in the economy including those exported to other countries. The index is more comprehensive as it takes into account government and household consumption and international trade. The GDP uses the Fisher's index—geometric mean of prices of goods and services in the base year and current year. Since the index takes into account prices in the base and current, it reduces the substitution bias—clients substitute cheaper goods for expensive goods.	1 – GPD deflator takes into the substitution effect. 2 – GDP deflator measures the annual price change and incorporates the whole aspect of the economy.	1 – The GDP deflator regarded as the best option among all methods, but it also does not take into account the quality of the goods and services and may be cumbersome to calculate all the prices and quantities in the economy.	World Bank: No recommendations Decision: The GDP deflator is used because it is the only available and recommended index inflation adjustment in low-income settings such as Kenya.	1,5
Personal Consumption Expenditure (PCE) price index	The PCE price index (Fisher's index) is used to reflect all personal expenditures including medical, education and other services as compared	1 - The PCE includes more expenditures including those paid by the third party (not	1 - The PCE index does not include government investments and expenditures.		5,6

	to the CPI that only accounts for consumption items.	government), which makes it a better estimate than the CPI. 2 - More appropriate when adjusting for changes in the purchasing power for personal consumption.			
Personal Health Care (PHC) expenditure deflator	The PHC index is a more specific and includes personal health expenditures (out-of-pocket and third-party payments). This index is built on the CPI-medical component, but the PHC also includes the third-party expenditures.	1 – The PHC index is more specific and appropriate for medical related expenditures compared to the general PCE or CPI.	1 – The PHC is not available in many countries and in the United States, the index is estimated after a 2-year lag.		[5,6]
The rate of wage inflation	This approach only measures the average increase in the wages in the whole economy or a given sector in the economy.	1 – The rate of wage inflation is more specific and may be more accurate and appropriate for wage adjustment.	1 – The rate of wage inflation is too narrow to apply as the general inflation index.		[1]
The rate of inflation for	This approach in applicable to a specific industry or sector. Some countries	1 – The method is more specific	2 – The index does not cover all potential costs to		[1]

specific products	produce the index for the health sector (goods and services).	and may be more accurate.	be applied broadly as the general inflation index. 3 - The index is also not readily available in most of the countries especially developing countries such as Kenya.		
WHO = World Health Organization guide to Cost-effectiveness analysis US Panel – The US Panel on Cost-effectiveness in Health and Medicine World Bank – Cost-effectiveness recommendation for disease control priorities					

Table S3: Currencies used for measuring and reporting costs.

Method	Description	Advantages	Disadvantages	Recommendations and Decision	Source
International dollar (I$)	An international dollar is a hypothetical currency, which has the same value as the US dollar and has the same purchasing power in every country. The international dollar is used in cost-effectiveness analysis because it enables easier cross-country comparisons of costs and interventions. The purchasing power of 1 I$ is the same in all countries. Costs reported in local currency are converted to international dollars using the purchasing power parity (PPP) exchange rate, which takes into account the country's standards of living.	1 - The international dollar enables cross-country comparison of costs and interventions especially when costs are collected from multiple sources and reported in different currencies.	1 - A large body of cost-effectiveness studies use market exchange rates and report costs in US dollars, which makes comparison with studies that use international dollars a challenge. 3 – Some regions don't have PPP exchange rates, which may limit the use of international dollars 2 – The international dollar is a hypothetical currency and costs in real life are measured in US dollars.	WHO: Recommends that costs are valued in international dollars to enable comparison of results across countries/settings. For interventions that are specifically local, and all prices are collected in local currency, WHO recommends using the local currency since it is more practical and useful to local policy makers. US Panel: No recommendations World Bank: Recommends using the international dollar and they base their recommendation on the WHO recommendation. Decision: I decided to report costs in international dollars to	[1,7]
US dollar (US $)	The US dollar is used in many cost-effectiveness studies given because most goods and services on international markets are traded in US dollars.	1 – The US dollar is more relatable given that prices of most of commodities on the international	1 – The US dollar does not account for differences in costs of goods that are not traded on international markets such as labor. Salaries vary across countries, and it is not		[1,7]

		market are traded in US dollars. 2 – The US dollar is appropriate to if all costs are coming from one country and there's no need for comparison of costs also multiple countries.	possible to assign a US dollar value that would represent the cost of labor in all countries.	facilitate comparison of cost-effectiveness results across other countries in the region. Truck drivers are a mobile population in the region and hence this intervention could be applied to another country in East and Southern Africa.	
Local currency (Kenyan Shilling)	Cost-effectiveness studies have used local currencies especially when the intervention is locally funded, and prices are all valued in local currency.	1 – Use of local currency is useful and practical to local policy makers given that budgets are done in local currency.	1 – Local currency is only practical to use when all costs are collected and reported in local currencies. 2 – The cost-effectiveness results are less likely to be generalizable and compared to other similar interventions in other setting when costs are reported in local currency.		1
WHO = World Health Organization guidelines to Cost-effectiveness analysis US Panel – The US Panel on Cost-effectiveness in Health and Medicine World Bank – Cost-effectiveness recommendation for disease control priorities					

Table S4: Statistical models used in the literature to estimate the relative risk of binary outcomes in non-clustered randomized controlled trials

Method	Description	Advantages	Disadvantages	Recommendations and Decision	Source
logistic regression model	The ordinary logistic regression model is the most commonly used model to estimate a binary outcome, but it produces only odds ratios instead of risk ratios (relative risk). Odds ratios are generated using a logit link function—logarithm of the ratio between success and failure of an intended outcome. The link function connects the model's outcome to its predictors. A method was developed by Jun Zhang to convert odds ratios generated by the logistic regression model to risk ratios (relative risk),[8] which has been widely used in medical and public health studies.	1 – The logistic regression model is easy, widely acceptable, and able to estimate relative risks in situations where more advanced models are not required.	1 – The method for converting odds ratios generated by the logistic regression model is likely to generate wide confidence intervals and has been found to be inconsistent.[9] 2 – The converted relative risk overestimates the risk ratio when the incidence of the outcome is more common (>10 percent)[10]	There is no gold standard statistical model that is recommended for estimating relative risks for cohort studies. However, the log-binomial model is recommended in literature since it generates more reliable confidence intervals. But, given the challenges of convergence of the log-binominal model, the Poisson model with robust-variance is recommended as an alternative model. The Poisson model overcomes the problem of failure to converge because it does not impose any restriction on the estimated parameters. We use a robust	[8–10]
log-binomial regression model	The log-binomial regression model is part of the Generalized Linear Models that assumes a linear relationship between the outcome and the predictors using the log link function. Since the outcome in this study is binary, the relationship between the outcome and the predictors is non-	1 - The log-binomial regression estimates the relative risks, which we need for estimating the incremental effectiveness of the intervention.	1 – The drawback of the log-binomial model is that in some situations it does not converge to produce the estimates.[3] The issue of convergence occurs because the log-binomial model imposes		

	linear. To generate the linear relationship, the link function transforms the outcome by taking the log of the mean of the outcome. Since the outcome has been transformed to a log of the mean of the outcome, we exponentiate the coefficients of the predictors to estimate the relative risk of the outcome for a unit change in the predictor.	2 - log-binomial produces unbiased estimates and smaller confidence intervals. 3 – Log-binomial is also the most commonly used model in literature, which makes our study comparable with other studies.	restrictions on the parameter space to prevent probabilities from exceeding 1 and when the maximum likelihood estimate (MLE) occurs at the boundary of the parameter space, the model fails to converge to find/generate the MLE estimate. Some studies have developed alternative methods to overcome the issue of convergence. For example, modifying the data so that the MLE estimate is within the parameter space (COPY method).[12,13] The COPY method uses multiple simulations to replicate the original data and estimate the relative risks. However, alternative models have been recommended than using the COPY method.	variance to minimize the likelihood of overestimating parameters. The Poisson regression model in equation (1) was used to estimate the relative risk. The model uses a log link function, which links the binary dependent outcome with the linear predictors. In this case, the log link function exponentiates the linear predictors to generate relative risk estimates per linear predictor.[11]	
Poisson regression model	Similar to the log-binomial model, the Poisson regression model is part of the generalized linear	1 – The Poisson regression model generates	1 – Poisson regression model is more preferred when the prevalence of		[2,14]

with a robust variance	models and uses the log-link function. Poisson regression model with a robust variance has been shown in literature to generate comparable results as the log-binomial model.[2] The robust variance is used because the Poisson regression model does not impose any restrictions to the estimated parameter and hence is likely to overestimate the bounds of the parameter estimate.[3]	comparable relative risk estimates to the log-binomial model and is recommended in literature as the ideal substitute when the log-binomial fails to converge.	the outcome is low but in our study the preference is high. However, the model is still able to generate correct estimates in high prevalence outcomes.		

Table S5: Statistical models used in the literature to estimate mean costs in randomized controlled trials

Method	Description	Advantages	Disadvantages	Recommendations and Decision	Source
Arithmetic mean	This method includes the summing up of total costs per trial arm and calculating the mean per trial arm. The means are compared to determine the difference between the two arms.	1 – This method is simple and easy to implement	1 – The arithmetic method does not take into account the distribution of the costs and the average my not be presentative of the true average cost per participant. This is particularly true if there are differences in baseline characteristics between subjects in the trial arms.[15]	In literature, there is no consensus on a single model to use for estimating mean costs per trial arm. However, the generalized linear gamma model is commonly recommended because it produces unbiased mean costs.	[15]
The ordinary least squares (OLS) regression	The OLS regression model is one of the commonly used multivariate models for estimating mean costs between the 2 trials arms. The OLS model is simple to implement and takes in to account the individual characteristics of the participants. OLS model assumes equal variance of costs across trial arms and the predicted mean is a linear combination of coefficients and control variables.	1 – The OLS model estimates mean costs difference between trial arms and accounts for variations across participants.	1 – OLS has a limitation of failure to take into account the skewed distribution of costs and since OLS is sensitive to outliers (extreme costs), the estimates may be innacurate.[16] 2 – OLS assumes equal variance across arms, which may not be always true. This limitation of extreme costs can be overcome by taking the log of costs but in some situations log of costs can does not wotk.[17] Such situations include: 1) when observations include zero costs; 2) when the distribution of log of costs is not normal; and 3) when there		[16]

			are differences in the variance of log of costs across trial arms.		
Generalized linear (gamma) models (GLM)	The generalized linear models are used to overcome the limitations of OLS models (does not assume constant variance and linear combination of coefficients and control variables). GLM (gamma) model uses a log link function which characterizes the relationship between the linear combination of coefficients and control variables with the predicted outcome. Unlike the OLS that models the log of the mean cost, the gamma models the mean of log cost, which overcomes the limitations OLS. To generate the arithmetic, we exponential the log of mean cost. GLM distributions includes Normal, Bernoulli, Binomial, Poisson, Gamma and Inverse Normal.[18] A review on regression models for analyzing cost data found that the gamma GLM is preferred estimating costs.[4]	1 – The gamma model does not assume equal variance and is not affected by skewed distribution of the data.	1 – The GML models have a limitation of failure to identify the correct link function to use prior to estimating the model. However, the log-link function has been shown to be the most applicable. Further, a number of diagnostic tests can be conducted to identify the correct link function These include: Pregibon link test,[19] which evaluates the linearity response of the estimation and the Hosmer-Lewshow test, which estimates the bias in the estimates.[20]		4,18–20

Descriptive statistics: Table S6 shows descriptive statistics for key variables by trial arm (CHIVST and SOC). We performed the chi-square test for categorical variables, Mann-Whitney U test for differences in Medians, and Fisher's exact test for small samples to test for differences between CHIVST and SOC arm. The descriptive statistics show that participants are not statistically different across trial arms.

Table S6: Descriptive statistics for the sample overall and by randomization arm

Variable	Total, n (column %)	SOC Arm, n (row %)	CHIVST Arm, n (row %)	P-value, chi-square test
Total	305	155 (50.8%)	150 (49.2%)	
Clinic where recruited				0.787
Clinic 1	144 (47.2%)	72 (46.5%)	72 (48.0%)	
Clinic 2	161 (52.8%)	83 (53.5%)	78 (52.0%)	
Age in years				0.989[1]
Mean (SD)	37.0 (7.9)	36.9 (8.0)	37. 2 (7.8)	
Median (Range)	36.0 (21.0 – 62.0)	35.0 (21.0 – 60.0)	37.0 (24.0 – 62.0)	
High school graduate				0.417
No	196 (64.3%)	103 (66.5%)	93 (62.0%)	
Yes	109 (35.7%)	52 (33.5%)	57 (38.0%)	
Mean trucking income per month (Kenyan Shillings)				0.074*
8,000–15,999 KES	15 (5.2%)	12 (8.1%)	3 (2.1%)	
16,000–23,999 KES	65 (22.6%)	33 (22.3%)	32 (22.9%)	
24,000–55,000 KES	208 (72.2%)	103 (69.6%)	105 (75.0%)	
Number of years worked as truck driver				0.650[1]
Mean (SD)	8.7 (7.1)	9.0 (7.8)	8.4 (6.3)	
Median (range)	6.7 (1.0 – 38.9)	6.7 (1.0 – 38.9)	6.7 (1.0 – 37.0)	
Clinic is on usual trucking route				0.573
No	51 (16.8%)	24 (15.6%)	27 (18.0%)	
Yes	253 (83.2%)	130 (84.4%)	123 (82.0%)	
Number of nights away from home in the past 30 days				0.495[1]
Mean (SD)	21.6 (5.6)	21.3 (5.9)	21.8 (5.3)	

Median (range)	22.5 (0.0 – 30.0)	22.0 (0.0 – 30.0)	23 (2.0 – 30.0)	
Came to the clinic specifically for HIV testing				0.365
No	173 (56.7%)	84 (54.2%)	89 (59.3%)	
Yes	132 (43.3%)	71 (45.8%)	61 (40.7%)	
Sexually active in the past 6 months				0.116[2]
No	6 (2.0%)	1 (0.7%)	5 (3.4%)	
Yes	295 (98.0%)	152 (99.3%)	143 (96.6%)	
Married (legal or common law)				0.998
No	51 (16.9%)	26 (16.9%)	25 (16.9%)	
Yes	251 (83.1%)	128 (83.1%)	123 (83.1%)	
Has other regular partner(s) on the trucking route				0.619
No	163 (53.4%)	85 (54.8%)	78 (52.0%)	
Yes	142 (46.6%)	70 (45.2%)	72 (48.0%)	
Paid for sex in the past 6 months				0.789
No	126 (44.1%)	65 (43.3%)	61 (44.9%)	
Yes	160 (55.9%)	85 (56.7%)	75 (55.1%)	
Always used condoms when had sex in the past 6 months (among those that had sex)				0.358
No	250 (85.9%)	127 (84.1%)	123 (87.9%)	
Yes	41 (14.1%)	24 (15.9%)	17 (12.1%)	
Ever tested for HIV before				0.259
No	25 (8.2%)	10 (6.5%)	15 (10.0%)	
yes	280 (91.8%)	145 (93.5%)	135 (90.0%)	
Number of years since last HIV test among those tested				0.934[1]
Mean (SD)	1.1 (1.6)	1.0 (1.4)	1.1 (1.9)	
Median (range)	0.5 (0.1 – 12.0)	0.5 (0.1 – 7.4)	0.5 (0.1 – 12.0)	
Ever self-tested for HIV among those who ever tested				0.171[2]
No	276 (99.3%)	142 (98.6%)	134 (100.0%)	
Yes	2 (0.7%)	2 (1.4%)	0 (0.0%)	

*** p<0.01, ** p<0.05, * p<0.1

[1]Mann-Whitney U test

[2]Fisher's exact test

Missing data

Table S7 shows the total number of participants in the sample and the missing data in each variable in the total sample and per trial arm. The percentage of patients missing data in all the variables is less than 10%. There is no consensus in literature on the minimum percentage of missing data that could bias the results. Missing data can be accounted for in 2 ways: 1) deleting observations with missing data or 2) imputing the missing data. Deleting observations with missing data may bias the results if the data is not missing completely at random, which means that patients that have missing data could be different from those that have data, and this may bias the results. Missing data may be imputed if it is not missing completely at random.

Table S7: Missing data in the total sample and across trial arms

Variable	Total Sample	Total Missing, n (%)	Choice Arm	SOC Arm
Choice arm	305			
Clinic visited	305			
Age	305			
Education level	305			
Income	288	17 (5.57%)	10	7
Years worked as a truck driver	302	3 (0.98%)		3
Clinic is on usual track route	304	1 (0.32%)		1
Number of nights away from home in the last 30 days	297	8 (2.6%)	4	4
Visited clinic to test for HIV	305			
Had sex in the last six months	301	4 (1.31%)	2	2
Married	302	3 (0.98%)	2	1
Has partner(s) on the trucking route	305			
Paid for sex in the past 6 months*	286	9 (3.05%)	7	2
Always used condoms when had sex in the past 6 months*	291	4 (1.36%)	3	1
Ever tested for HIV before	305			
Number of years since last HIV test among those tested	276	29 (9.51%)	18	11
Ever self-tested	278	27 (8.85%)	16	11

* The question was asked among those that reported to have had sex in the last 6 months.

Examining missing data in the analytical sample

Before accounting for the missing data, we first identified variables to include in our study. Explanatory variables (Table S8) were considered based on theoretical and contextual significance to HIV testing uptake and this study. Among the four explanatory variables, only one variable (payment for sex in the last six months) had missing data—9 (3%) participants were missing data of which 7 were in the CHIVST arm and 2 in the SOC arm. We examined the missing data and found the data were missing completely at random across trial arms. Considering that data was missing completely at random, we did not impute the missing data and patients with missing data were excluded from the analysis.

Table S8: Justification for the variables included in the regression model

Variable	Justification for inclusion
Clinic visited	We included the clinic where participants tested because randomization was done at the clinic. There is a possibility of differences across clinics that are not accounted for in the data that could impact the outcome. For example, the staff at the clinic may treat patients differently.
Visited the clinic to test for HIV	We controlled for the reason a participant visited the clinic to account for those that may have tested for HIV regardless of the intervention.
Paid for sex in last 6 month	Payment for sex is a high-risk behavior that is associated with increased risk of acquiring HIV. In literature, men who perceived to have a high risk of acquiring HIV were more likely to test for HIV compared to those that perceived lower risk.[21]
Age	Age is associated with HIV testing uptake with more older individuals likely to test for HIV compared to the young, but the evidence is mixed. In some studies, adults compared to adolescents have shown more uptake of HIV testing services,[22] while others have shown more uptake among adolescents[21,23] and age having no effect on HIV testing.[24] The variation in association of age with HIV testing uptake across studies could be attributed to different age groups compared and study settings.

Univariate analysis

We conducted a univariate analysis to determine the individual effect of the variables on the uptake of HIV testing services. Table S9 shows that only four variables are statistically significant. Four variables (trial arm, clinic visited, if a patient visited the clinic to test for HIV and payment for sex in the last 6 months) were statistically significant.

Table S9: Univariate analysis on the HIV testing uptake

Variable	Sample Size	Odds Ratio	95% CI
Choice arm	305	2.56***	[1.40 – 4.66]
Clinic visited	305	0.10***	[0.04 – 0.23]
Age	305	1.00	[0.97 – 1.04]
Visited clinic to test for HIV	305	8.01***	[3.54 – 18.5]
Paid for sex in the past 6 months	286	2.51***	[1.38 – 4.54]

*** p<0.01, ** p<0.05

Economic costs data sources

Economic cost data (Table S10) came from peer-reviewed and grey literature. Costs incurred in the trial were first identified by reviewing the report that summarized the implementation and findings from the trial.[25] Costs including SOC HIV test kit, HIV self-testing kit, nurse salary, training, cell phone service, equipment (mobile phone) and patient time came from the trial report.[25] Costs for health facility, health facility staff and overhead came from a costing analysis study within the same setting and study population.[26] Since SOC HIV test kits were offered for free at the clinic, we identified the cost of SOC HIV test in Kenya[27] to examine the impact of SOC HIV test kit cost variation in the sensitivity analysis. Finally, the cost of medical supplies (Table S11) came from an HIV testing study in Kenya.[28]

Table S10: Selected data sources for HIV testing costs, derived from literature

Cost component	Country	Year of the data	Currency	Reported Unit	Baseline [Range]	Source
SOC HIV test kit	Kenya	2015	USD	Per test kit	0.00	25
	Kenya	2012	USD	Per test kit	0.79*	27
HIV self-testing kit	Kenya	2015	USD	Per test kit	7.54	25
Medical supplies	Kenya	2014	USD	Per HIV test	0.14 [0.07 – 0.21] †	28
	Kenya	2014	USD	Per HIV test	0.23 [0.12 – 0.35]	28
Nurse salary	Kenya	2015	USD	Per hour	1.50	25
One-time training	Kenya	2015	USD	Per patient	0.04	25
Health facility staff	Kenya	2016	USD	Per HIV test	0.51	26
Health facility	Kenya	2016	USD	Per HIV test	0.83	26
Overhead	Kenya	2016	USD	Per HIV test	2.05	26
	Kenya	2016	USD	Per patient	1.08‡	26
Cell phone service	Kenya	2015	USD	Per HIV test	6.60	25
Equipment (mobile phone)	Kenya	2015	USD	Per patient	1.20	25
Patient time	Kenya	2015	KES	Per hour	165.72 [160.99 – 170.46]	Trial data

* Applicable only in the one-way sensitivity analysis

†Applicable to patients that tested using self-administered oral HIV testing at the clinic.

‡ Applicable to patients that tested using self-administered oral HIV testing at home.

Table S11: Cost of medical supplies

Type of cost performed	Medical supplies	Unit	Cost (USD 2014)
SOC	Dual safe powdered gloves	per person tested	$ 0.06
	Capillary tubes	per person tested	$ 0.04
	Medimax cotton wool	per person tested	$ 0.01
	Hand sanitizer	per person tested	$ 0.06
	Alcohol swabs	per person tested	$ 0.03
	Biohazard bags	per person tested	$ 0.02
	lancets	per person tested	$ 0.01
	Sum	per person tested	$ 0.23
CHIVST (HIV self-test at the clinic)	Dual safe powdered gloves	per person tested	$ 0.06
	Hand sanitizer	per person tested	$ 0.06
	Biohazard bags	per person tested	$ 0.02
	Sum	per person tested	$ 0.14

Steps for converting costs from original currency to 2017 international dollars

1. Covert all costs to a common unit; per-patient cost
2. Covert cost estimate to Kenya currency using the exchange rate indicated in the data source
3. Adjust the costs for inflation to 2017 Kenyan currency year
4. Covert costs to 2017 international dollar currency year

Table S12: Economic costs (2017 I$) considered in this study

Cost component†	Unit	SOC arm [Range]	CHIVST arm [Range]			Source
			SOC	Self-test (clinic)	Self-test (home)	
SOC HIV test kit	Per patient	0.00 [0.00 – 0.00]	0.00 [0.00 – 0.00]	—	—	[25]
	Per patient	1.43	1.43	—	—	[27]
HIV self-testing kit	Per patient	—	—	15.52 [7.76– 23.28]	15.52 [7.76–23.28]	[25]
Medical supplies	Per patient	0.42 [0.21 – 0.63]	0.42 [0.21 – 0.63]	0.26 [0.13 – 0.38]	—	[28]
Nurse	Per patient	2.27 [1.13 – 3.40]	2.27 [1.13 – 3.40]	2.84 [1.42 – 3.40]	2.84 [1.42 – 3.40]	[25]
One-time training	Per patient	—	0.09 [0.05 – 0.14]	0.09 [0.05 – 0.14]	0.09 [0.05 – 0.14]	[25]
Health facility staff	Per patient	1.10 [0.55 – 1.65]	1.10 [0.55 – 1.65]	1.10 [0.55 – 1.65]	0.47 [0.24 – 0.71]	[26]
Health facility	Per patient	1.72 [0.86 – 2.57]	1.72 [0.86 – 2.57]	1.72 [0.86 – 2.57]	0.74 [0.37 – 1.12]	[26]
Equipment (Phone)	Per patient	—	2.47 [1.23 – 3.70]	2.47 [1.23 – 3.70]	2.47 [1.23 – 3.70]	[25]
Cell phone service	Per patient	—	13.65 [6.82 – 20.47]	13.65 [6.82-20.47]	13.65 [6.82-20.47]	[25]
Overhead	Per patient	4.24 [2.12 – 6.36]	4.24 [2.12 – 6.36]	4.24 [2.12 – 6.36]	2.26 [1.13 – 3.38]	[26]
Patient time*	Per patient	2.51 [2.43 – 2.58]	2.51 [2.43 – 2.58]	3.13 [3.04 – 3.22]	3.13 [3.04 – 3.22]	[25]

*Patient time cost was estimated based on average income (trial data) lost for the time spent at the time during the HIV testing process which took 40, 50, and 50 minutes for participants that used the provider-administered test, self-testing at the clinic and self-testing at home, respectively. Using data from the trial, we estimated the mean wages per hour, assuming a 40-hour week schedule and multiplied it with the time spent at the clinic to calculate the patient time cost. The time spent at the clinic for HIV testing was significantly different across trial arms. The cost of pre- and post-test counseling was estimated at 20 minutes and the actual HIV testing process was also estimated at 20 minutes, for participants in both the CHIVST and SOC arm, totaling to 40 minutes per patient.[25] Participants that opted for HIV self-testing had an additional time of 6.5 minutes to watch the demonstration video on how to use the HIV self-testing kit. After watching the demonstration video, participants had questions regarding the HIV self-testing, and the total time was estimated at 10 minutes, including watching the video.[25] We assumed that participants who tested from home used the same time (20 minutes) for the actual HIV testing as those that tested from the clinic using the HIV self-testing. In summary, the HIV testing process took 40, 50, and 50 minutes for participants in the standard of care, HIV self-testing at the clinic and at home, respectively. We tested for the difference in mean time across trial arms using the "t-test" and the difference was statistically significant.

†All cost boundaries, apart from patient time where we had access to personal level data from the trial, were estimated as 0.5 and 1.5 of baseline value for the lower and upper bound, respectively because data sources did not report ranges or confidence intervals.

Table S13: Results from the multi-way sensitivity analysis

Domain	Scenario*	Estimate	95% CI
Incremental Effectiveness (NNT)	N/A	6.25	[5.00 – 8.33]
Incremental Cost			
	Base case	26.20	[23.32 – 29.09]
	Best case	13.47	[11.89 – 15.05]
	Worst case	38.94	[34.74 – 43.13]
Incremental cost-effectiveness ratio			
	Base case	163.77	[151.57 – 175.37]
	Best case	84.19	[77.95 – 90.12]
	Worst case	243.36	[225.15 – 260.57]

Abbreviations: NNT = Number Needed to Treat; N/A = Not Applicable

*The base case considers costs at baseline value; best case considers only low bound costs; and worst case considers only the upper bound costs for each cost component.

Supplementary materials for paper two

Analytical decisions

Methodological approach: We used a mathematical model (a single cohort state transition model) due to its ability to examine alternative strategies and project future costs and health benefits using multiple data sources. This methodology has been implemented in literature to examine HIV prevention and treatment strategies,[29,30] especially when observational data from one source is unavailable to perform statistical analysis. Although the single cohort state transition model does not capture individual heterogeneity that reflects the real world, it provides an insight in the potential cost-effectiveness of the strategies when data is unavailable to apply more advanced methods such as micro-simulation.[31]

Model structure: The model has 24 health states (including death) based on natural history disease progression stratified based on CD4 cell count disease stages and engagement in clinical HIV care. The clinical stages of HIV natural disease progression are defined based four CD4 cell count strata: Asymptomatic Early (corresponding with CD4 count >500 cells/μL); Asymptomatic Late (>350 - 500 cells/μL); Symptomatic (>200 – 350 cells/μL); and AIDS (≤200 cells/μL)). The 4 CD4 strata enables estimation of health benefits and economic costs for early diagnosis and engagement in care vs engagement in care at later stage of the disease.[30,32] Patients diagnosed in early stages of the disease and immediately initiated on ART experience lower risk of morbidity and mortality compared to those that are diagnosed at late stages of the disease.[33,34] However, CD4 stratification assumes similar behavior for the whole fraction of the cohort within the stratum, which may not be the case. We include six stages of engagement in HIV care (undiagnosed, diagnosed, liked to care, First-line ART, Second-line ART and lost from care). HIV diagnosis and linkage to care are modeled as separate health states to account for lower rates of linkage to care among community-based HIV testing approaches compared to facility-based approaches.[35] As test and treat policy implementation improves in sub-Saharan Africa, separating HIV diagnosis and linkage may underestimate the benefits of people starting ART on the same day. First- and second-line ART are modeled separately to account for more costly second-line ART costs.[36]

Time horizon. We examined costs and health benefits using a lifetime horizon. A number of cost-effectiveness analysis studies in literature using a Markov model have considered a lifetime time horizon while assessing efficiency of HIV prevention strategies.[37–40]

Cycle length: We used a monthly cycle length to account for timely linkage to care and ART initiation. The recommended time for linkage to care and ART initiation after being diagnosed with HIV is 30 days. Although test and treat has been implemented in East and Southern Africa,[41,42] linkage to care is still low among hard-to-reach population and the cycle length of one month will account for the timely linkage to care.[43]

Discount rate: We discounted future economic costs and health benefits at 3% to convert future values to present values.[1] People usually value things more in the present than in future so by discounting we account for that time preference. Although the discount rate of 3% is recommended by the WHO, there is less agreement on the true discount rate.[1] The application of a uniform discount rate overtime may not be true given that other variables change overtime including preferences.[44] In sensitivity analysis, we assess the impact of the discount rate on the incremental cost-effectiveness ratio by varying the discount rate between 0 and 5%.

Measure of effectiveness: Health benefits were measured as disability-adjusted life years (DALYs) averted. DALYs lost are the recommended measure of health benefits in cost-effectiveness analysis conducted in low-income countries as they estimate the overall burden of the disease (healthy life years lost due to both premature mortality and living with disability).[1]

DALYs is a standard measure of the burden of disease and can be compared across multiple conditions and cost-effectiveness analysis (CEA) studies. Monthly disability weights came from Eaton et al.,[29] and were derived from the global disease burden study.[45] Disability weights were applied to each health state based on the disease stage. All ART health states had the same disability weight regardless of the disease stage to account for ART health benefits.

Study perspective: This study was conducted from a societal perspective. The World Health Organization recommends conducting cost-effectiveness studies from a societal perspective, which takes into account direct health (e.g., clinical services and medications) and non-health (e.g., patient time and transport cost to the healthcare facility) related costs of a health intervention for a society as a whole regardless of who is paying.[1] In this study, I included patient time spent at the healthcare facility to seek care and transport costs.

Parameter inputs

Initial distribution: An initial hypothetical cohort, 30-year-old, undiagnosed, individuals living with HIV is based on the CD4 distribution of newly diagnosed HIV individuals in Kenya.[46] To our knowledge, no study has reported CD4 cell count distribution for newly diagnosed female sex workers (FSWs) and truck drivers in Eastern and Southern Africa. We assumed the CD4 distribution stratification in the general population would be comparable to that of FSWs and truck drivers.

Probability of disease progression: Data for disease progression came from a study conducted in south Africa that examined community-based strategies to improve HIV care with parameter inputs derived from observational data.[30] In our model, we assumed that fractions of the cohort that experience disease progression are in undiagnosed, diagnosed, linked and lost health states. Those in ART health states don't experience disease progression due to the benefits of ART. Although fluctuations on CD4 cell count occur among patients on ART, data to inform the parameters inputs were unavailable.

Probability of death: Data for the probability of death among people living with HIV (PLWH) who are not on treatment came from a longitudinal study in South Africa.[47] Due to lack of CD4 cell count specific data in high-risk populations, we used data from PLWH in the general population.[47] For PLWH and on antiretroviral therapy (ART), we assume their mortality rate reduces by 58% compared to those not on ART.[48] Previous studies have shown that the impact of ART on population level mortality rate ranging from 25%[49] - 90%.[50] Although gender variations in mortality rate in PLWH exist,[51] we assumed that this variation is already accounted for in the background mortality adjustment, thus ART is assumed to have an equal impact on men and women. In addition, the mortality rate was assumed to be same for patients on first-line ART and second-line ART.[52] We accounted for age and gender specific background mortality using lifetables from the World Health Organization (WHO).[53] The adjustment and calculation of monthly probability of death is done in three steps:

1. Add the annual HIV mortality rate to the age-specific background annual mortality rate from the WHO.
2. Calculate the monthly mortality rate by dividing by 12
3. We convert the monthly mortality rate to probability of death.

The relationship between a rate and probability is expressed as: $Rate = \frac{-\ln(1-p)}{t}$, where r = rate, p = probability, t = time period.

Probability of being reached for HIV testing: The probability of being reached varied by the type of strategy (facility-based vs community-based), gender (women vs men) and disease stage. Based on evidence from the general population, community-based strategies are likely to reach more people including men, particularly those that are less likely to visit health-facilities for care (e.g., HIV testing).[54] We assume that truck drivers, whom the significant majority are men, are less likely to access care or be reached by facility-based strategies compared to female sex workers who are women.[55] For facility-based strategies, one study that interviewed truck drivers at truck stops reported that only 36% of truck drivers used roadside wellness clinics for the past year, with 64% reporting either not using the clinics or unaware of the roadside wellness clinics.[56] We assume female sex workers are 50% more likely as truck drivers to visit a health facility at least once within a year to seek care. For community-based strategies, we assume that both truck drivers and female sex workers have the same likelihood of being reached. Based on a meta-analysis, 67% reported to have met or been reached by a peer educator with a period of 12 months.[57] Based on previous work done on truck drivers and female sex workers,[58–61] a significant majority are below 50 years. We assume that these individuals (50+ years) comparable access to care as people in the general population and are likely to visit the health facility at least once a year due to multiple conditions that are prevalent within this age group.[62,63]

Probability of testing: This probability of testing varies based on the strategy, gender (men vs women), age and disease stage. Since all truck drivers are men and female sex workers are women, we considered differences in their health care seeking behaviors are compared to men and women in the general population. Probability of HIV testing by will vary age as strategies targeting high-risk populations will only be applicable to 49 years and below those 50+ years old considered as part of the PLWH in general population

and use the standard of care and are 50% less likely to test for HIV compared to those less than 50 years.[64] We assume that HIV testing is offered ounce a year per strategy. We examined six alternative strategies including: 1) voluntary counseling and testing (VCT),[65] 2) provider-initiated and -administered HIV testing and counseling (PITC),[66] 3) peer educator direct delivery of HIV self-testing kits in the community (HIVST Kit Delivery),[67] 4) peer educator delivery of coupons in community to exchange for an HIV self-test kit at the healthcare facility (HIVST Coupon Delivery),[67] 5) peer educator referral to facility-based for a provider-administered HIV test (VCT Referral),[67] 6) provider-initiated offer of oral HIV self-testing or provider-administered HIV testing (HIVST Choice).[66] The HIVST Choice and PITC are based on a randomized controlled trial conducted among 305 truck drivers in Kenya in 2015 that offered the choice of provider-administered HIV testing or HIV self-testing at the clinic, or home vs only the provider-administered HIV testing.[66] Three other strategies (HIVST Kit Delivery, HIVST Coupon delivery, and VCT Referral) are based on a randomized controlled trial conducted among FSWs in Uganda in 2017 that examined the effectiveness of HIV testing delivery strategies.[67] The sixth strategy, VCT, is the standard of care.[65]

- Probability of testing among truck drivers
    - Kit Delivery: The probability of HIV testing for the Kit Delivery strategy is based on an RCT conducted among FSWs where 92.9% tested for HIV.[67] Since self-testing is equally acceptable among men,[54,68,69] we assume equal probability of HIV testing among truck drivers. Although no study has been done among truck drivers, previous work done among men who have sex with men (MSM) —a high-HIV-risk group— suggests that using peer-educators to distribute kits for HIV self-testing at the healthcare facility is effective (95% uptake) at improving HIV testing.[70]
    - Coupon Delivery: The probability of HIV testing for the Coupon Delivery strategy is also based on an RCT conducted among FSWs where 76.8% tested for HIV.[67] Although coupons are delivered in the community, individuals have to visit the health facility to pick HIV self-test kits. For truck drivers, we assume that coupons are delivered to drivers at truck stops and the probability of testing will be half (38.4%) of that of FSWs since men are less likely to visit the healthcare facility to seek care as compared to women.
    - VCT Referral: The probability of HIV testing for the Referral strategy is also based on an RCT conducted among FSWs where 68.9% tested for HIV.[67] Similar to the HIVST coupon delivery strategy, we assume that the probability for truck drivers testing for HIV will be half (34.5%) of that of FSWs since it requires visiting the clinic to get tested for HIV.
    - HIVST Choice: The probability of HIV testing is based on an RCT where truck drivers in the intervention were offered the choice of provider-administered HIV testing or HIV self-testing at the clinic, or home vs only the provider-administered HIV testing.[66] In the intervention, 87.3% of drivers tested for HIV.
    - Provider-initiated and -administered: Similar to the HIVST Choice strategy, we use the control arm of the RCT[66] to estimate the probability of truck drivers testing for HIV when the provider only offers the provider-administered test. In the control arm, 72.9% of drivers tested for HIV.

- VCT: Based on data from the RCT[66], 40.5% of truck drivers who visited the clinic and agreed to participate in the study, had specifically come to test for HIV and actually tested for HIV.

- Probability of testing among female sex workers
  - The probability of testing for HIV for the HIVST kit delivery; HIVST coupon delivery and VCT referral was based on an RCT conducted among FSWs in Uganda where 92.9%, 76.8% and 68.9% tested for HIV, respectively.[67]
  - HIV self-testing Choice: Although no study has been conducted to offer a choice of self-testing in addition to the standard of care among FSWs at the healthcare facility, previous work has shown high (95%) acceptability of oral self-testing among FSWs.[71,72] We assume that FSWs will likely have a high uptake of HIV testing when offered the choice of HIVST compared to truck drivers.
  - PITC: The probability of HIV testing among FSWs in this strategy was 90% based on previous work that has shown high acceptability[73–75] of HIV testing in FSWs at the healthcare facility, ranging from 74%[74] to 100%[75].
  - VCT: This is the standard of care strategy and the probability of HIV test uptake is 23.4%.[60] The probability of VCT testing for FSWs is lower than for truck drivers. This is counterintuitive given that women are more likely to use healthcare services compared to men. Although FSWs are likely to visit the healthcare facility, they tend to seek care for other health conditions but less for HIV prevention or HIV cares services.[60] A potential examination for this case could be that many FSWs fear the stigma from the community being aware of their HIV status and health provider discrimination. Alternatively, FSWs may be receiving HIV testing through during antenatal visits and also there are many programs focusing on HIV testing and care for female sex workers compared to truck drivers.[76]

HIV test sensitivity: The sensitivity of the first HIV test is strategy specific, but the confirmatory test and tiebreaker test are the same across all strategies. Strategies (HIVST Kit Delivery, HIVST Coupon Delivery and HIVST Choice) that offered the oral self-administered test used the Oral Sure OraQuick test, sensitivity (95% confidence interval) = 92% (66.0 – 99.0).[77,78] Strategies (VCT Referral, HIVST Choice, PITC, VCT) that offered the blood-based provider-administered test used KHB colloidal Gold test, sensitivity (95% CI) = 100.0% (97.4 – 100.0).[79] The Self-testing Choice uses both the Oral Sure OraQuick and KHB colloidal Gold test for individuals that tested using the self-administered test and provider-administered respectively. The sensitivity of the Self-testing Choice strategy is a pooled estimate based on the percentage of individuals that tested using the self-administered (73%) and provider-administered test (27%).[66] The HIV test algorithm in Kenya includes a confirmatory (First Response 1-2.0) and tiebreaker (Uni-Gold) test, which have a sensitivity (95% CI) of 100.0% (97.4 – 100.0) and 96.4% (91.8 – 98.8).[79]

Probability of test results discloser and receipt of a confirmatory test: The probability of disclosing test results after taking an HIV test varies based on the strategy setting (community-based vs facility-based). We assume that all (100%) individuals who test from the health-facility and have a reactive test will disclose their results to the healthcare provider and also get a confirmatory test as recommended in the HIV testing algorithm in Kenya.[66,79] Previous studies conducted in the general population have reported wide

variations on estimates for confirmatory test uptake. In Kenya, 60% of individuals were willing to get a confirmatory after an HIV self-test.[80] One study that examined partner testing through distribution of self-tests suggested that more than 50% of those that tested positive received a confirmatory test.[81] In another study, only 25% (2 of 8 that tested positive) of individuals that tested positive received a confirmatory test but the study couldn't confirm if the other individuals received HIV care from another health facility.[82] In Malawi, 56% of individuals that self-tested received a timely confirmatory test.[83] Little has been done in high-risk populations. In Kenya, willingness to receive a confirmatory test was 40% and 75% among MSM and female sex workers, respectively.[80] In another study, 44%, 24% and 64% of female sex workers that had a positive reactive test in the kit delivery, coupon delivery and VCT visited the clinic for HIV care.[67] Among the community-based strategies examined in our study, they use peer-educators who followed up on the individuals to make sure they used the HIV test and inquired to seek care if they tested positive. This may improve the percentage of individuals getting a confirmatory test after a reactive test. We assume that 90% of those that test outside the healthcare facility will seek timely care given that peer educators follow-up with nudge HIV positive individuals to seek care. The probability of discloser of test results and receipt of a confirmatory test for the HIVST Choice strategy is a pooled estimate based on the percentage of individuals that tested at health facility (91.5%) and home (8.5%).[66]

Probability of linkage to care: The probability of timely linkage to care[67] was the same across all strategies but varies by disease stage. All individuals, irrespective of the strategy, have to visit the health facility to get a confirmatory test before they considered diagnosed of HIV.

Probability of ART initiation: The probability of ART initiation was the same across all strategies and doesn't vary by disease stage since based on the current guidelines of treat all.[84] In Kenya, 83% of initiate ART within 30 days.[85]

Lost from care: The probability of loss from care varied by engagement in care (pre-ART and on ART), gender and risk.[86–88] Although studies have found advanced HIV disease stage (AIDS vs non-AIDS) has higher loss to follow up, the differences between AIDS vs non-AIDS haven't been statistically significant.[86,88] Further, the higher loss to follow up in advanced disease stages may be a misclassification of death as loss to follow-up.[89–93] Evidence from people living with HIV in the general population shows that Pre-ART patients have higher LTFU compared to ART patients, with Pre-ART patients nearly twice as likely as ART patients to be lost from care.[87] Since no study has examined differences in loss to follow up among high-risk populations, we base on general population evidence[87,94] to assume that Pre-ART patients are twice as likely as ART patients to be lost from care. Men are 1.5 times more likely to be LTFU compared to women.[86] Patients 50+ years old have a lower risk of LTFU compared to 49 years and below.[95]

Costs: HIV testing costs (Table A1) include fixed costs (healthcare facility, equipment such as phones); medical costs (HIV test kit[43,96–99] and medical supplies); personnel (medical and non-medical healthcare facility staff, and peer-educators), training, overhead costs, and patient costs (patient time and transport to the health facility). The cost of a confirmatory and tiebreaker test were considered as an

independent HIV test at a healthcare facility with all cost components of a standard HIV testing and counseling process applicable.[27,79] The costs for the initial test in Kit delivery, Coupon delivery and VCT referral strategy came from the randomized controlled trial report.[43] Costs VCT and PITC came from a costing study on HIV testing in Kenya.[99] Cost for patients in pre-ART and ART care came from a report on costing analysis of compressive HIV care by the ministry of health in Kenya.[100] All costs were estimated in three steps:

1. Convert costs from their original currency and year to Kenyan shillings
2. Convert costs to 2017 Kenyan shillings using the GDP deflator
3. Convert costs to 2017 international dollars

Table S14: Advantages and disadvantages for the analytical decisions

Analytical decision	Advantages	Disadvantages
Using a mathematical model methodology	• Mathematical models enable the analyst to examine scenarios that would be more complex in the real-world setting. For example, I am able to examine alternative strategies that were implemented in different settings at different time points, which would have been impossible to implement in the real-world. • Mathematical models enable the analyst to better understand the impact of various degrees of variable on an outcome that would be hard to change in the real-world setting. • Mathematical models enable the analyst to project future outcomes for various interventions. For example, in paper 2 and 3, I am able to project outcomes over a lifetime time horizon.	• Mathematical models are usually based on certain assumptions that may not be realistic in a real-world setting.
Using a single cohort state transition model.	• State-transition models provide the flexibility of examining economic costs and health benefits of alternative strategies, which may be costly or unethical to implement in the real world. • State-transition models can evaluate hypothetical scenarios to provide insight on outcomes of potential interventions if implemented in the real world. • State-transition models provide the flexibility to examine outcomes of strategies beyond the time period of the existing data. • State-transition models are straightforward to debug thus minimizing potential coding error	• State transition models assume that the probabilities are not dependent on history (e.g., previous states or time spent in a state), which is not always the case. • The single cohort state transition model does not capture individual heterogeneity that reflects the real world. Related approaches, such as micro-simulation models, address this limitation[31]
Model structure: Natural history disease progression as four CD4 strata	The clinical stages of HIV natural disease progression are defined based 4 CD4 cell count strata: Asymptomatic Early (corresponding with CD4 count >500 cells/μL); Asymptomatic Late (>350 - 500 cells/μL); Symptomatic (>200 – 350 cells/μL); and AIDS (≤200 cells/μL)). • The 4 CD4 strata enables estimation of health benefits and economic costs for early diagnosis and engagement in care vs engagement in care at later stage of the disease.[30,32] Patients diagnosed in early stages and immediately initiate ART	• The CD4 stratification assumes similar behavior for the whole fraction of the cohort within the stratum, which may not be the case.

	experience lower risk of morbidity and mortality compared to those that are diagnosed at late stages of the disease.[33,34]	
Model structure: six-stage engagement in HIV care	• HIV diagnosis and linkage to care are modeled as separate health states to account for lower rates of linkage to care among community-based HIV testing approaches compared to facility-based approaches.[35] • First- and second-line ART are modeled separately to account for more costly second-line ART costs.[36]	• As test and treat policy implementation improves in sub-Saharan Africa, separating HIV diagnosis and linkage may underestimate the number of people starting ART on time.
Health benefits: disability adjusted life years (DALYs) lost	• DALYs lost are the recommended measure of health benefits in cost-effectiveness analysis conducted in low-income countries as they estimate the overall burden of the disease (healthy life years lost due to both premature mortality and living with disability).[1] • DALYs is a standard measure of the burden of disease and can be compared across multiple conditions and CEA studies using DALYs.	• DALYs only measure the health benefit of an individual without accounting for the societal impact of the disease. For example, it's impact on education and future employment.[101] • The application of disability weights in DALYs has been questioned due lack of a valid standard measure including the ethical aspect of allocating statistical value on someone's life.[101]
Lifetime analytic time horizon	• The lifetime horizon enables the analyst to capture future costs and health benefits of a strategy. • Cost-effectiveness analysis studies on this topic have generally considered a lifetime time horizon. By implementing a similar time horizon, our findings will be comparable to literature.[37–40]	• Although a lifetime time horizon is suitable for examining the impact of strategies for chronic conditions such as HIV, in the real world, policy and other decision makers typically have relatively short time horizons for programmatic planning and implementation goals (e.g., 5, 10 or 20 years).
Monthly cycle length	• Although test and treat has been implemented in East and Southern Africa,[41,42] linkage to care is still low among hard-to-reach population and the cycle length of one month will account for the timely linkage to care.[43]	• In the era of test and treat, there is a possibility of more than one event (linkage to care and ART initiation)

		occurring within a one-month cycle.[43]
Discount rate of 3 percent	• I discount future economic costs and health benefits to convert future values to present values.[1] People usually value things more in the present than in future so by discounting I account for that time preference.	• Although the discount rate of 3% is recommended by WHO, there is less agreement on the true discount rate.[1] • The application of a uniform discount rate overtime may not be true given other variables change overtime including preferences change overtime.[44]

Figure S1: Efficiency frontier for HIV testing strategies among female sex workers

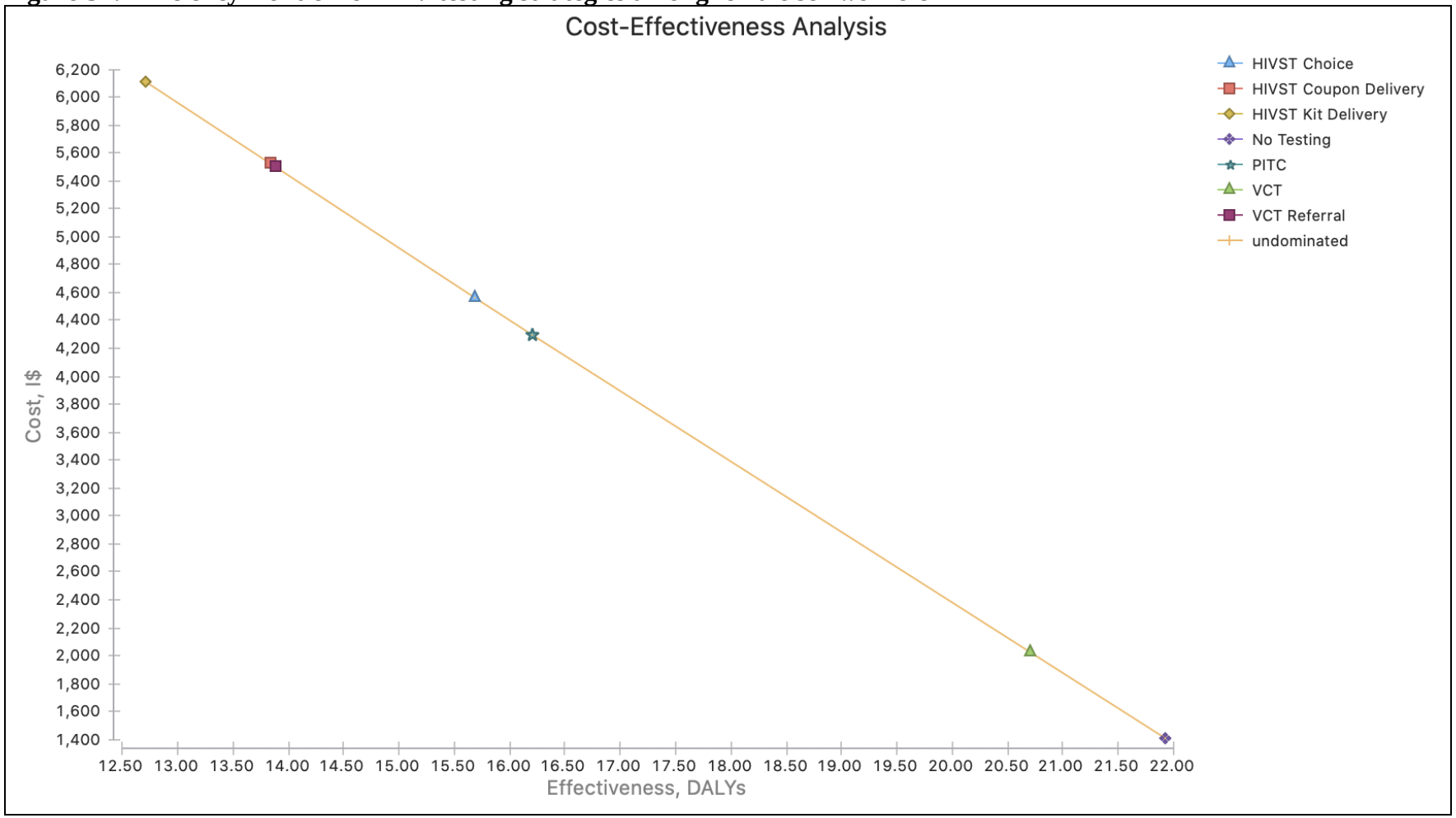
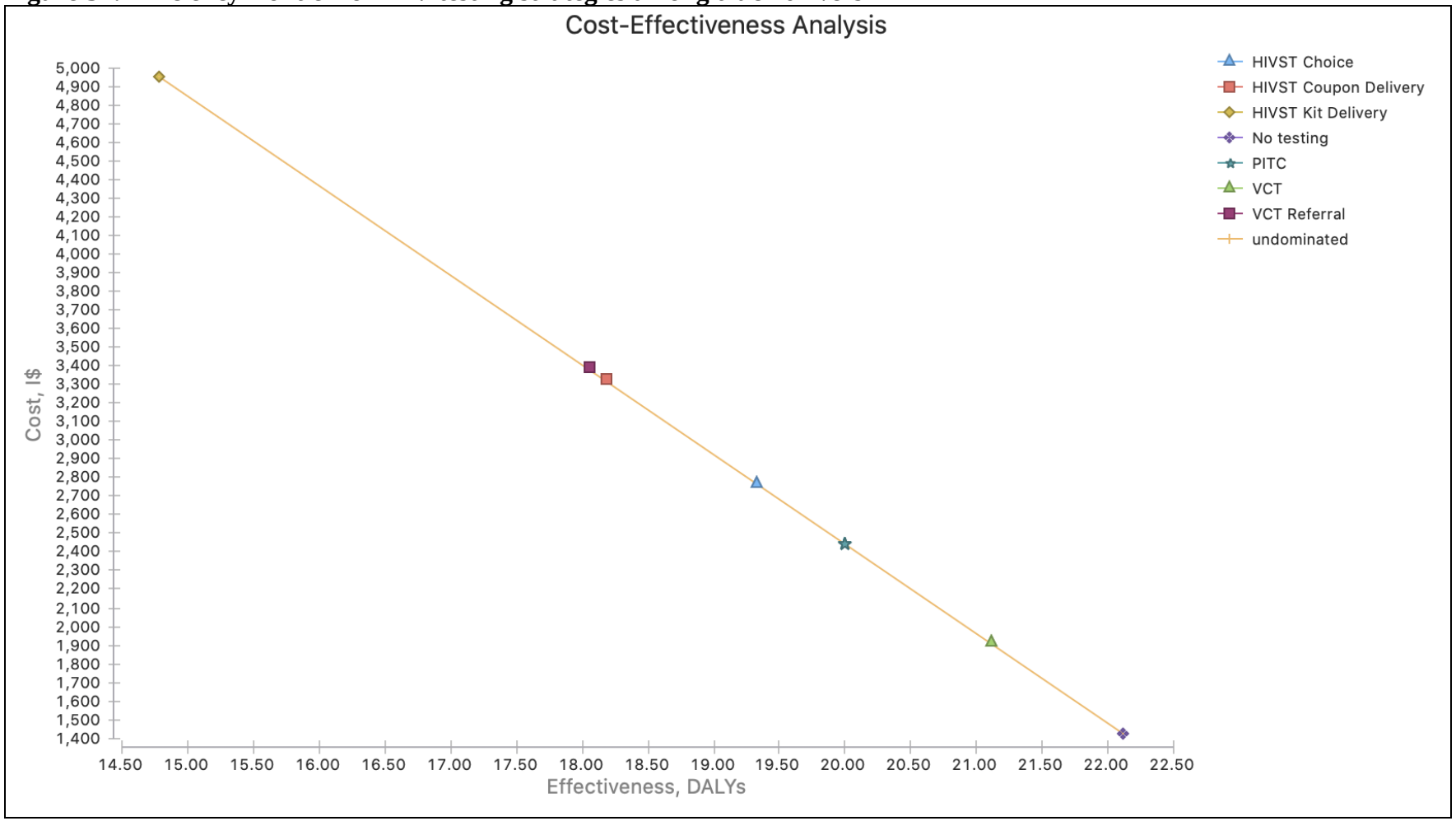


Figure S2: Efficiency frontier for HIV testing strategies among truck drivers



Cost-effectiveness results for the base case analysis considering a payer perspective

Table S15: Discounted base case cost-effectiveness results¶

Domain*	HIV Testing Strategy	Costs ($)	Incremental Cost ($)	DALYs Lost	DALYs Averted	ICER†
			Female Sex Workers			
Health facility	No Testing	$ 1,405		21.93		
	Voluntary testing	$ 1,854		20.70		
	Provider-initiated testing	$ 3,491	$ 2,086	16.20	5.73	$ 364
Combination	HIVST Choice	$ 3,682	$ 191	15.69	0.51	$ 373
	HIV testing referral card	$ 4,359		13.88		
	HIVST coupon delivery	$ 4,385		13.83		
Community	HIVST kit delivery	$ 4,797	$ 1,114	12.70	2.98	$ 374
			Truck Drivers			
Health facility	No testing	$ 1,425		22.11		
	Voluntary testing	$ 1,711		21.11		
	Provider-initiated testing	$ 2,152		19.99		
Combination	HIVST Choice	$ 2,381		19.32		
	HIVST coupon delivery	$ 2,784		18.18		
	HIV testing referral card	$ 2,825		18.04		
Community	HIVST kit delivery	$ 3,934	$ 2,509	14.77	7.34	$ 342

Abbreviations: HIVST = HIV self-testing, DALYs = Disability Adjusted Life Years, ICER = Incremental cost effectiveness ratio

*Strategies are classified by setting including health facility only, community only and a combination of both the health facility and the community setting.

†ICER is expressed as incremental cost/DALYs averted.

§Compared to "No testing" strategy.

¶Costs (2017 $) and health benefits are discounted at 3% per annual.

Scenario analysis: Assuming a FSW or truck driver will visit the health facility once a year

Table S16: Cost-effectiveness results when an individual visits a health facility at least once a year

Domain*	HIV Testing Strategy	Costs ($)	Incremental Cost ($)	DALYs Lost	DALYs Averted	ICER†
			Female Sex Workers			
Health facility	No Testing	$ 1,405		21.93		
	Voluntary testing	$ 3,442		17.93		
	HIV testing referral card	$ 5,503	$ 4,749	13.88	9.34	$ 508
Combination	HIVST coupon delivery	$ 5,535		13.83		
	HIVST kit delivery	$ 6,107		12.70		
	Provider-initiated testing	$ 6,154		12.59		
Community	HIVST Choice	$ 6,297	$ 143	12.32	0.98	$ 530
			Truck Drivers			
Health facility	No testing	$ 1,425		22.11		
	HIVST coupon delivery	$ 3,331		19.82		
	HIV testing referral card	$ 3,391		18.19		
Combination	Voluntary testing	$ 3,598		17.97		
	Provider-initiated testing	$ 4,553		18.05		
	HIVST Choice	$ 4,870	$ 3,445	17.11	7.18	$ 480
Community	HIVST kit delivery	$ 4,948	$ 78	14.78	0.15	$ 516

Abbreviations: HIVST = HIV self-testing, DALYs = Disability Adjusted Life Years, ICER = Incremental cost effectiveness ratio
*Strategies are classified by setting including health facility only, community only and a combination of both the health facility and the community setting.
†ICER is expressed as incremental cost/DALYs averted.
§Compared to "No testing" strategy.
¶Costs (2017 $) and health benefits are discounted at 3% per annual.

Supplementary materials for paper three

Table S17: Summary of the literature on PrEP effectiveness among hard-to-reach and general HIV populations

Intervention	Hard to reach population		General population	
	Intervention description	**Outcome, [range] (95% CI)**	**Intervention description**	**Outcome, [range] (95% CI)**
PrEP (Prospective study design)	Population: Female sex workers Country: Benin Design: Prospective cohort Sample size: 256 Year: 2018 Follow up time: 24 months Primary outcome: HIV incidence Secondary outcome: Adherence (self-reported) Study aim: To examine the impact of PrEP (emtricitabine/tenofovir disoproxil fumarate) on new HIV infections.[102]	HIV incidence = 0.8 (0.3-1.9) per 100 person years Adherence = [57—78%]	Population: General population (Serodiscordant Couples) Country: Kenya and Uganda Design: Prospective cohort Sample size: 1013 couples Year: 2012 Follow up time: 21 months Primary outcome: HIV incidence Secondary outcome: Adherence (monthly drug count). Study aim: To examine the impact of PrEP (emtricitabine/tenofovir disoproxil fumarate) on new HIV infections.[103]	HIV incidence = 0.2 (0.0-0.9) per 100-person years Adherence >85%
	Population: Female sex workers Country: South Africa Design: Prospective cohort Sample size: 219 Year: 2017 Follow up time: 12 months Primary outcome: HIV incidence Secondary outcome: Adherence (self-reported) Study aim: To examine the impact of PreP (Truvada) on HIV incidence in HIV negative FSWs.[104]	No new infections Adherence [70—85%]		

PrEP (RCT study design)	Population: MSM Country: Peru, Ecuador, South Africa, Brazil, Thailand, and US* Design: RCT Sample size: 2,499 (1,224 in intervention and 1,217 in control) Year: 2010 Follow up time: 34 months Primary outcome: HIV incidence Secondary outcome: Adherence (self-reported) HIV negative MSM were recruited to examine the impact of daily emtricitabine and tenofovir disoproxil fumarate on preventing new HIV infections.[105]	HIV incidence: 1.08 vs 1.93 per 100 person years in the intervention and control respectively. Efficacy (Tenofovir-emtricitabine) 44% (15 – 63) Adherence=95% (Not different across groups)	Population: General population Country: Kenya and Uganda Design: RCT Sample size: 4,747 (1,584 in tenofovir; 1,579 in tenofovir-emtricitabine and 1,584 in the placebo group) Year: 2012 Follow up time: 36 months Primary outcome: HIV incidence Secondary outcome: Adherence (monthly drug count). The aim of the study was to examine the impact of PrEP on new infections.[106]	HIV incidence: 1.99 vs 0.65 vs 0.5 per 100 person-years for placebo, Tenofovir and tenofovir-emtricitabine, respectively. Efficacy (Tenofovir) 67% (44 – 81) Adherence = 92% (Not different across groups)
	Population: Injection drug users Country: Thailand Design: RCT Sample size: 2,413 (1,204 in tenofovir &1,209 in placebo group) Year: 2013 Follow up time: 84 months Primary outcome: HIV incidence Secondary outcome: Adherence (drug dairies) An RCT among injection drug users examined impact of (tenofovir) on the risk of getting HIV compared a placebo.[107]	HIV incidence: Tenofovir 0.35 (0.21-0.56) Vs Placebo 0.69 (0.47 – 0.96) per 100 person years Efficacy (Tenofovir) 48% (10 – 72) Adherence=84% (Not different across groups)	Population: General population Country: Botswana Design: RCT Sample size: 1,219 (611 in tenofovir-emtricitabine and 608 placebo group) Year: 2012 Follow up time: 45 months Primary outcome: HIV incidence Secondary outcome: Adherence (drug count). The study aim was to examine the impact of PrEP on new HIV infections.[108]	HIV incidence: Tenofovir-emtricitabine - 1.2 Vs placebo – 3.1 per 100 person years. Efficacy (Tenofovir-emtricitabine) 62% (21 – 84) Adherence=84.1% (Not different across groups)

*The number of participants from the US was less than 10%.

Table S18 show supporting evidence that adherence on ART and PrEP are comparable to further justify the decision to use PreP as a proxy measure of behavior for individuals on ART.

Table S18: Systematic reviews and meta-analyses examining adherence to ART vs adherence to PrEP

ART adherence		**PrEP adherence**	
Study description	**Adherence estimate (95% CI), [Range]**	**Study description**	**Adherence estimate (95% CI), [Range]**
Design: Meta-analysis and systematic review Sample size: 146 studies Year published: 2016 Outcome: Adherence Study aim: To examine determinants of adherence to antiretroviral therapy in sub-Saharan Africa.[109]	72.6% (Pooled average adherence across studies)	Design: Meta-analysis and systematic review Sample size: 7 studies Year published: 2016 Outcome: Adherence Study aim: To examine the efficiency of PreP in preventing HIV-1 infection among women.[110]	Range (66-81%)
Design: Meta-analysis and systematic review Sample size: 50 studies Year published: 2014 Outcome: Adherence Study aim: To examine levels of adherence to antiretroviral therapy among adolescents.[111]	84% (79–89) (Pooled average adherence across studies)	Design: Meta-analysis and systematic review Sample size: 13 studies Year published: 2017 Outcome: Adherence Study aim: To examine the efficiency of PreP in preventing HIV-1 infection among adolescents.[112]	Range (51-82%)
Design: Meta-analysis and systematic review Sample size: 14 studies Year published: 2019 Outcome: Adherence Study aim: To examine impact of antiretroviral therapy adherence interventions among women living with HIV.[113]	75% [48-79] (Median adherence across studies)	Design: RCT* Population: MSM and Female sex workers Year published: 2012 Outcome: Adherence Study aim: To examine adherence and safety of PrEP among MSM and female sex workers in Arica.[114]	Adherence varied based on measurement method. Daily medication event monitoring system for daily dosing - 83% [IQR: 63–92]

Design: Meta-analysis and systematic review Sample size: 20 studies Year published: 2019 Outcome: Adherence Study aim: To examine differences in antiretroviral therapy adherence between older adults with younger adults in Africa.[115]	Older adults - 72% Young adults - 68% (Pooled average adherence across studies)	Design: systematic review Sample size: 13 studies Year published: 2016 Outcome: Adherence Study aim: To examine the efficiency of PreP in preventing HIV-1 infection in women.[116]	Range (67-83%)

*This study was considered because it only focused on high-risk populations (MSM and FSW) and there is no meta-analysis that only considered these populations.

Table S19: Potential candidate cost data for LTFU strategies and ART-related costs to inform economic unit costs

Cost Component	Country	Year of data	Currency	Unit costs	Original estimate (range)	Source
Community health worker salary	Uganda	2007	USD	Per month	35.00 (2.00 – 75.00)	[117]
	South Africa	2012	USD	Per patient month	(1.88 – 3.43)	[118]
	Sub-Saharan Africa	2012	USD	Per month	63.00 (2.00 – 294.00)	[119]
	Malawi	2014	USD	Per month	100.00	[120]
	Ethiopia	2014	USD	Per month	46.00	
	Kenya	2014	USD	Per month	23.00	
	Mozambique	2014	USD	Per month	40.00	
One-time training for community health worker	South Africa	2012	USD	Per patient year	5.97	[121]
Community health worker transport	Uganda	2007	USD	Daily	3.00	[117]
Clothing for community health worker	South Africa	2012	US	Per patient year	0.15	[121]
Management and administration for community health workers	South Africa	2012	USD	Per patient year	0.48	[121]
Monitoring and evaluation for community health workers program	South Africa	2012	USD	Per patient year	0.10	[121]
Salary for tracker – tracing patients	South Africa	2010	USD	Per patient month	3.70	[122]
	South Africa	2010	USD	Per patient month	2.14	[122]
Expenses for tracing patients	South Africa	2010	USD	Per patient month	0.57	[122]
Expenses for tracing patients	South Africa	2010	USD	Per patient month	0.57	[122]

Nutrition support to patients	Rwanda	2006	USD	Per patient year	128.00	[123]
	Uganda	2010	USD	Per patient year	538.00	[124]
	Senegal	2017	USD	Per patient day	0.99	[125]
	Mozambique	2009	USD	Per patient 3months	140.26	[126]
Breakfast	Côte d'Ivoire	2006	USD	Per patient month	1.00	[127]
ART-related costs sources						
Health Facility staff	South Africa	2012	USD	Per patient year	0.48	[121]
	Uganda	2012	USD	Per patient year	65.54	[128]
	Uganda	2010	UGX	Per patient year	55,000	[129]
	Uganda	2016	USD	Per patient year	51.08	[130]
	Kenya	2011	USD	Per patient year	38.44	[100]
Overhead costs	South Africa	2012	USD	Per patient year	0.99	[121]
	Uganda	2012	USD	Per patient year	47.09	[128]
	Uganda	2010	UGX	Per patient year	85,000	[129]
	Uganda	2016	USD	Per patient year	5.33	[130]
	Kenya	2011	USD	Per patient year	17.63	[100]
Health Facility and Equipment	South Africa	2012	USD	Per patient year	0.02	[121]
	Uganda	2016	USD	Per patient year	6.57	[130]
	Kenya	2011	USD	Per patient year	9.08	[100]
Laboratory costs	Uganda	2012	USD	Per patient year	20.94	[128]
	Rwanda	2012	USD	Per patient year	15.00	[131]
	Malawi	2012	USD	Per patient year	5.00	[131]
	Ethiopia	2012	USD	Per patient year	16.00	[131]
	Zambia	2012	USD	Per patient year	13.00	[131]
	Zambia	2010	USD	Per patient year	69.94	[132]
	Uganda	2010	UGX	Per patient year	111,000.00	[129]
	Kenya	2011	USD	Per patient year	19.30	[100]
Opportunistic infections	Uganda	2012	USD	Per patient year	42.85	[128]
	Burkina Faso	2008	USD	Per patient month	0.60	[133]
	South Africa	2009	USD	Per patient year	96.00	[134]
	Ghana	2012	USD	Per patient year	(9.94 – 39.86)	[135]

	Kenya	2011	USD	Per patient year	8.51	[100]
	Uganda	2010	UGX	Per patient year	11,000.00	[129]
Opportunity cost of time for seeking care	Ghana	2009	USD	Per patient month	2.74	[136]
	South Africa	2010	USD	Per patient month	12.04	[137]
	Côte d'Ivoire	2014	USD	Per patient month	9.38	[138]
	Kenya	2011	USD	Per patient month	2.83	[100]
Transport to the clinic	South Africa	2009	USD	Per patient month	6.00	[122]
	South Africa	2017	USD	Per patient month	2.80	[139]
	Uganda	2010	UGX	Per patient year	7,069.00	[129]
	Uganda	2007	USD	Per patient month	(1.75 – 11.50)	[140]
	Uganda	2015	USD	Per patient month	1.89	[141]
	Kenya	2011	USD	Per patient year	33.80	[100]
First line ART						
TDF/3TC/EFV	LIC	2017	USD	Per patient year	90.00	[36]
	LIC	2016	USD	Per patient year	100.00	[142]
TDF/FTC/EFV	LIC	2017	USD	Per patient year	90.00	[36]
	LIC	2016	USD	Per patient year	106.00	[142]
AZT/3TC/EFV	LIC	2016	USD	Per patient year	164.00	[142]
Second Line ART						
AZT+3TC+ATV/r	LIC	2017	USD	Per patient year	233.00	[36]
	LIC	2016	USD	Per patient year	286.00	[142]

Abbreviations: LIC = Low-income countries; CHAI = Clinton Health Access Initiative; MSF = Medecins Sans Frontieres

Table S20: Cost-effectiveness results associated with different initial distributions

Initial Distribution	Strategy	Cost	Incremental cost	DALYs Lost	DALYs Averted	ICER
	No Intervention	$ 2,449.59		9.98		
	ART delivery	$ 3,087.43	$ 637.83	9.02	0.96	$ 660
	Tracing + Transport	$ 3,732.24		9.53		
	Medical care + Transport + Breakfast	$ 4,110.88		8.99		
All cohort with	Tracing + Medical care	$ 4,681.14		8.81		
CD4>500	ART delivery + Nutrition	$ 9,849.08	$ 6,761.65	7.60	1.42	$ 4,700
	No Intervention	$ 2,859.77		10.69		
	ART delivery	$ 3,437.80	$ 578.02	9.55	1.15	$ 500
All cohort with	Tracing + Transport	$ 4,258.12		10.15		
CD4 500 - >350	Medical care + Transport + Breakfast	$ 4,571.81		9.51		
	Tracing + Medical care	$ 5,167.03		9.30		
	ART delivery + Nutrition	$ 10,418.27	$ 6,980.47	7.92	1.63	$ 4,300
	No Intervention	$ 3,409.62		11.68		
	ART delivery	$ 3,919.99	$ 510.37	10.28	1.40	$ 360
All cohort with	Tracing + Transport	$ 4,976.13		11.00		
CD4 >350 - <200	Medical care + Transport + Breakfast	$ 5,208.80		10.23		
	Tracing + Medical care	$5,841.41		9.99		
	ART delivery + Nutrition	$ 11,221.68	$ 7,301.70	8.37	1.91	$ 3,800
	No Intervention	$ 3,323.55		13.40		
	ART delivery	$ 3,528.45	$ 204.90	12.78	0.62	$ 330
	Tracing + Transport	$ 4,701.29		13.07		
	Medical care + Transport + Breakfast	$ 4,702.99		12.77		
All cohort with	Tracing + Medical care	$ 5,206.65		12.69		
CD4 ≤200	ART delivery + Nutrition	$ 9,156.46	$ 5,628.00	12.27	0.51	$ 10,900
>500 = 0.42	No Intervention	$ 3,018.00		11.77		
500 - >350 = 0.25	ART delivery	$ 3,446.14	$ 428.15	10.86	0.91	$ 470
>350 - <200 = 0.21	Tracing + Transport	$ 4,398.94		11.32		
≤200 = 0.12	Medical care + Transport + Breakfast	$ 4,588.11		10.83		
	Tracing + Medical care	$ 5,143.12		10.68		
	ART delivery + Nutrition	$ 9,842.42	$ 6,396.28	9.72	1.14	$ 4,800

Abbreviations: ART = Antiretroviral Therapy; DALYs = Disability Adjusted Life Years; ICER = Incremental cost-effectiveness ratio

Table S20 shows results for the variation of the initial distribution. Results were consistent with the baseline findings. ART Delivery was cost-effective with an ICER less than $700 compared to No Intervention when all the initial cohort was assumed to start at CD4 strata >500, 500 - >350, <350 - >200 and ≤200. Further, ART Delivery with nutrition supplement was cost-effective at a WTP threshold of 3xGDP of Kenya ($4,700), when all the initial cohort started at CD4 strata >500, 500 - >350 and <350 - >200 but not ≤200. This suggests that ART Delivery with nutrition supplement maybe cost-effective in reducing LTFU if FSWs living with HIV are on treatment at early stages of HIV.

Figure S3: Efficiency frontier for LTFU strategies in the base case analysis

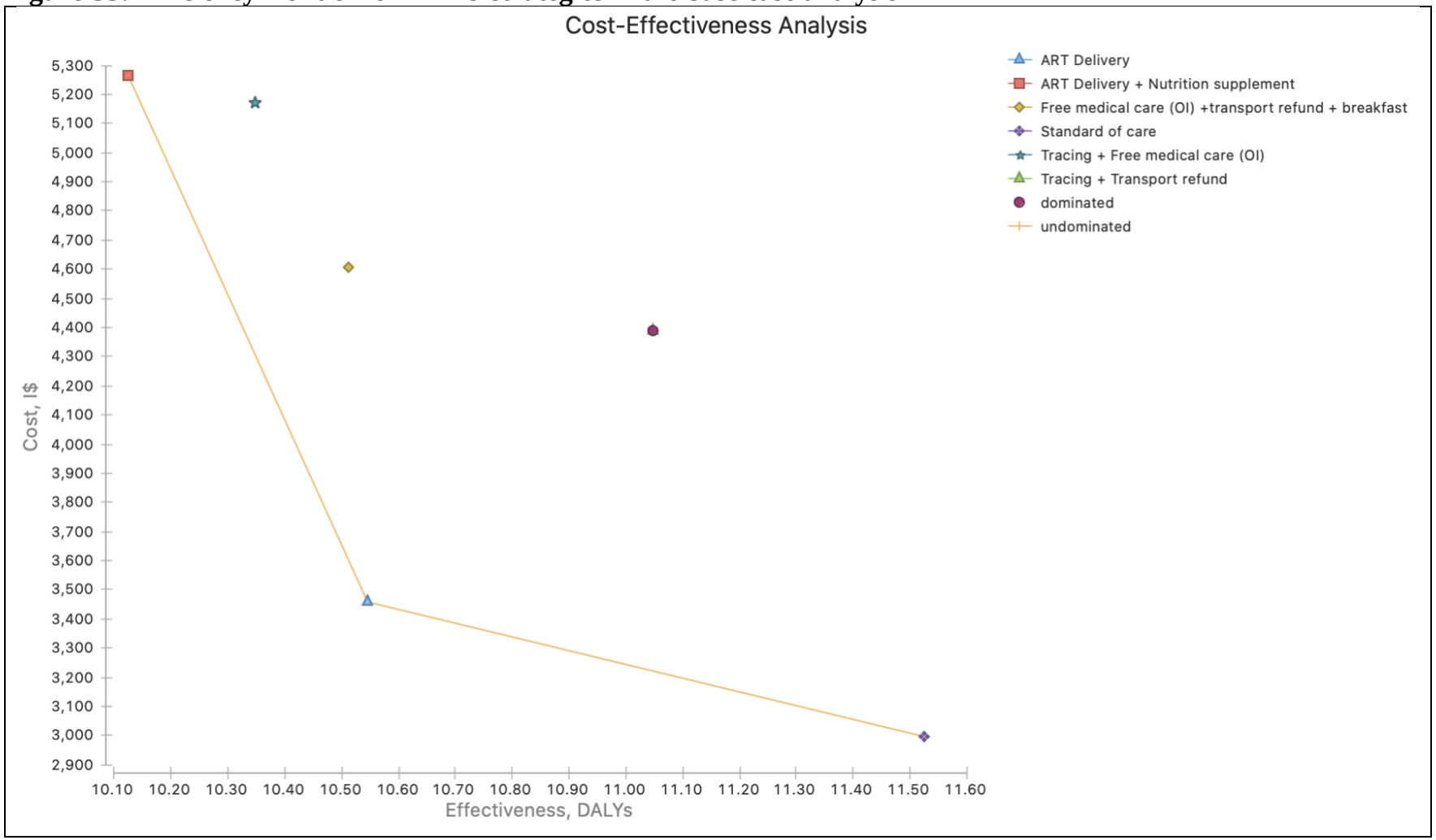


Figure S4: Cost-effectiveness results when we assume nutrition supplement is offered for only 5 years

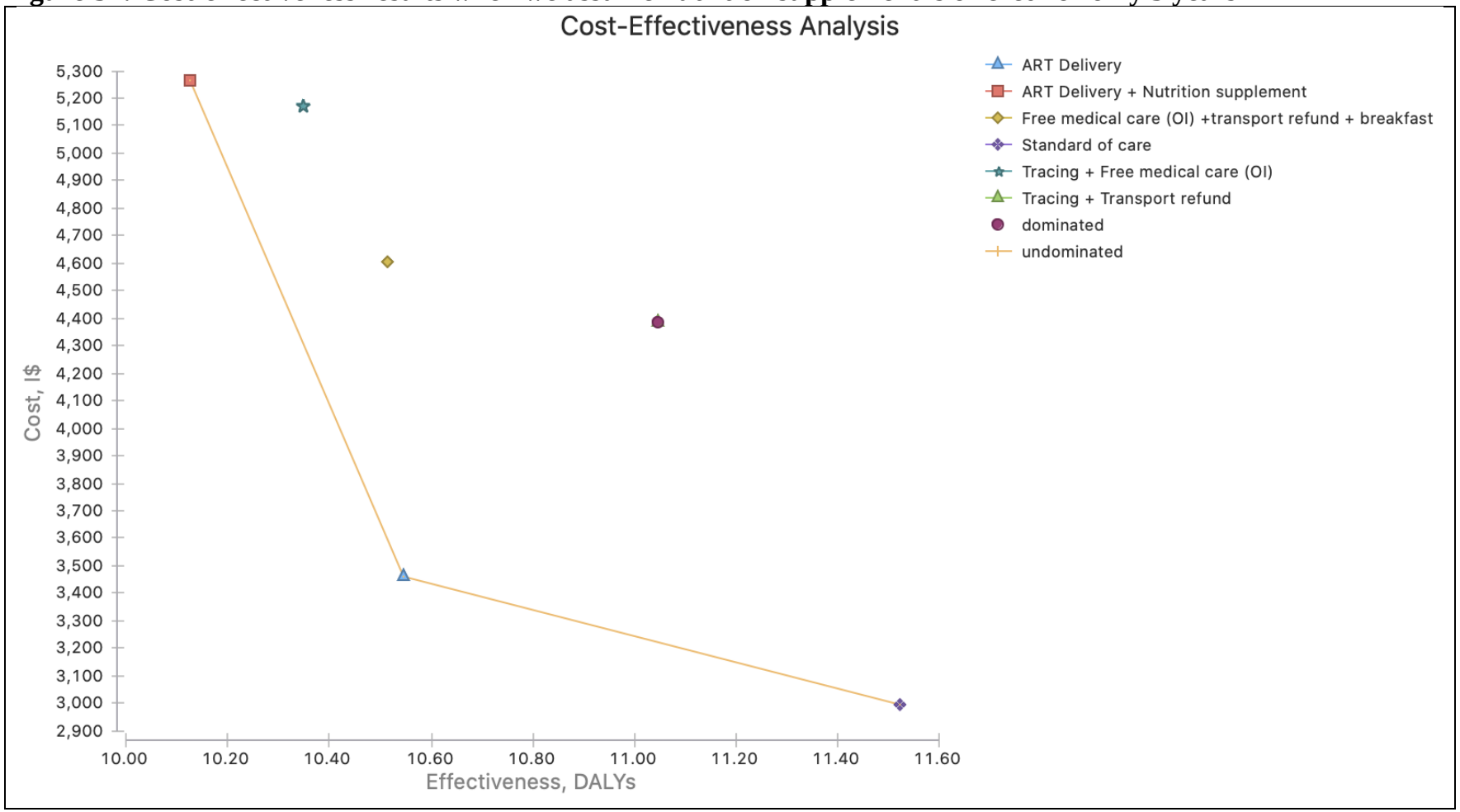


Table S21: Cost-effectiveness results when we assume nutrition supplement is offered for only 5 years

Strategy	Cost	Incremental cost	DALYs Lost	DALYs Averted	ICER
No Intervention	$ 2,994.56		11.52		
ART delivery	$ 3,460.73	$ 466.17	10.55	0.98	$ 470
Tracing + Transport	$ 4,386.60	--	11.05		abs. dominated
Medical care + Transport + Breakfast	$ 4,606.21	--	10.51		ext. dominated
Tracing + Medical care	$ 5,173.28	--	10.35		ext. dominated
ART delivery + Nutrition	$ 5,263.00	$ 1,802.00	10.12	0.42	$ 4,300

Abbreviations: ART = Antiretroviral Therapy; DALYs = Disability Adjusted Life Years; ICER = Incremental cost-effectiveness ratio

Figure S5: Cost-effectiveness results when we assume nutrition supplement is offered for only 10 years

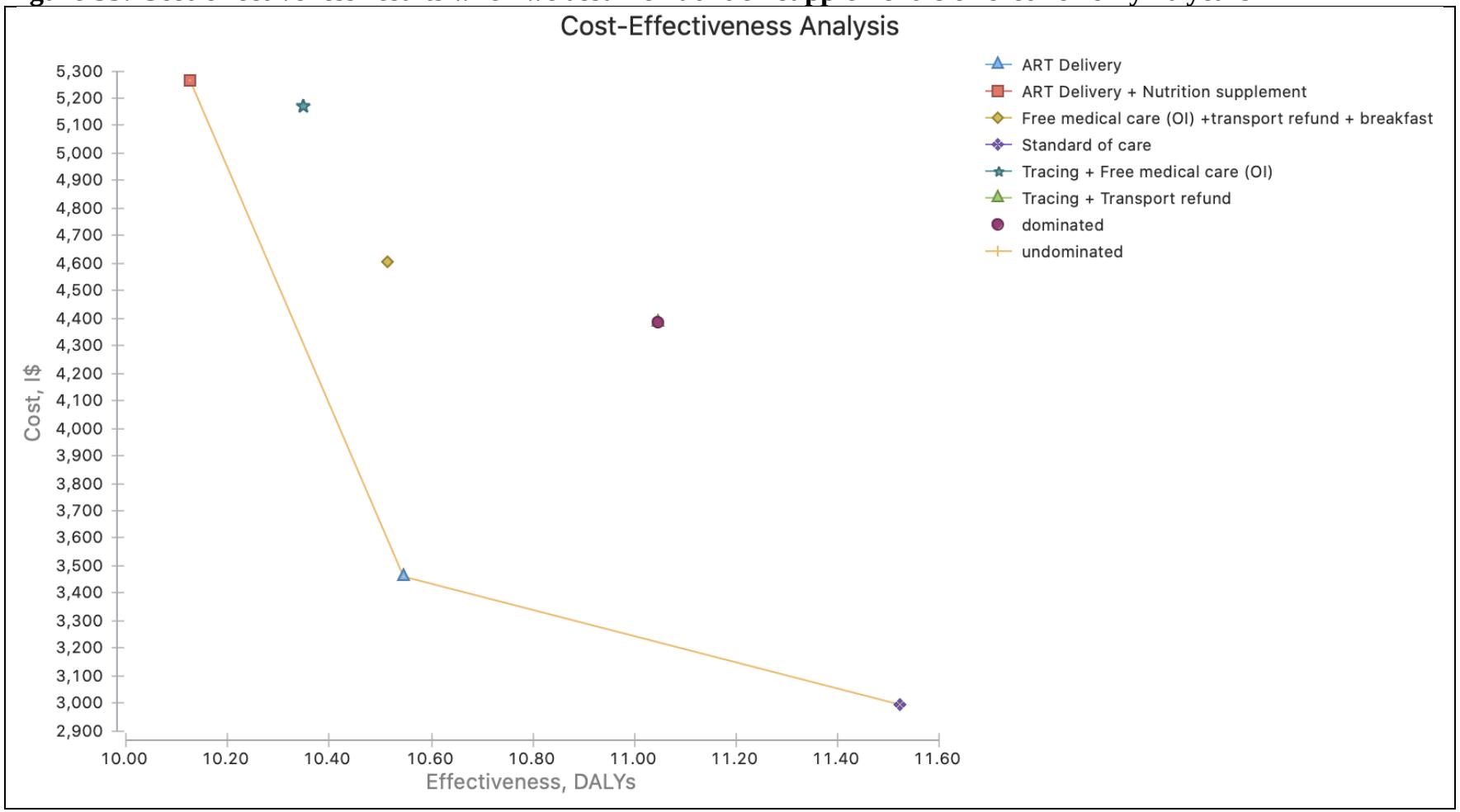
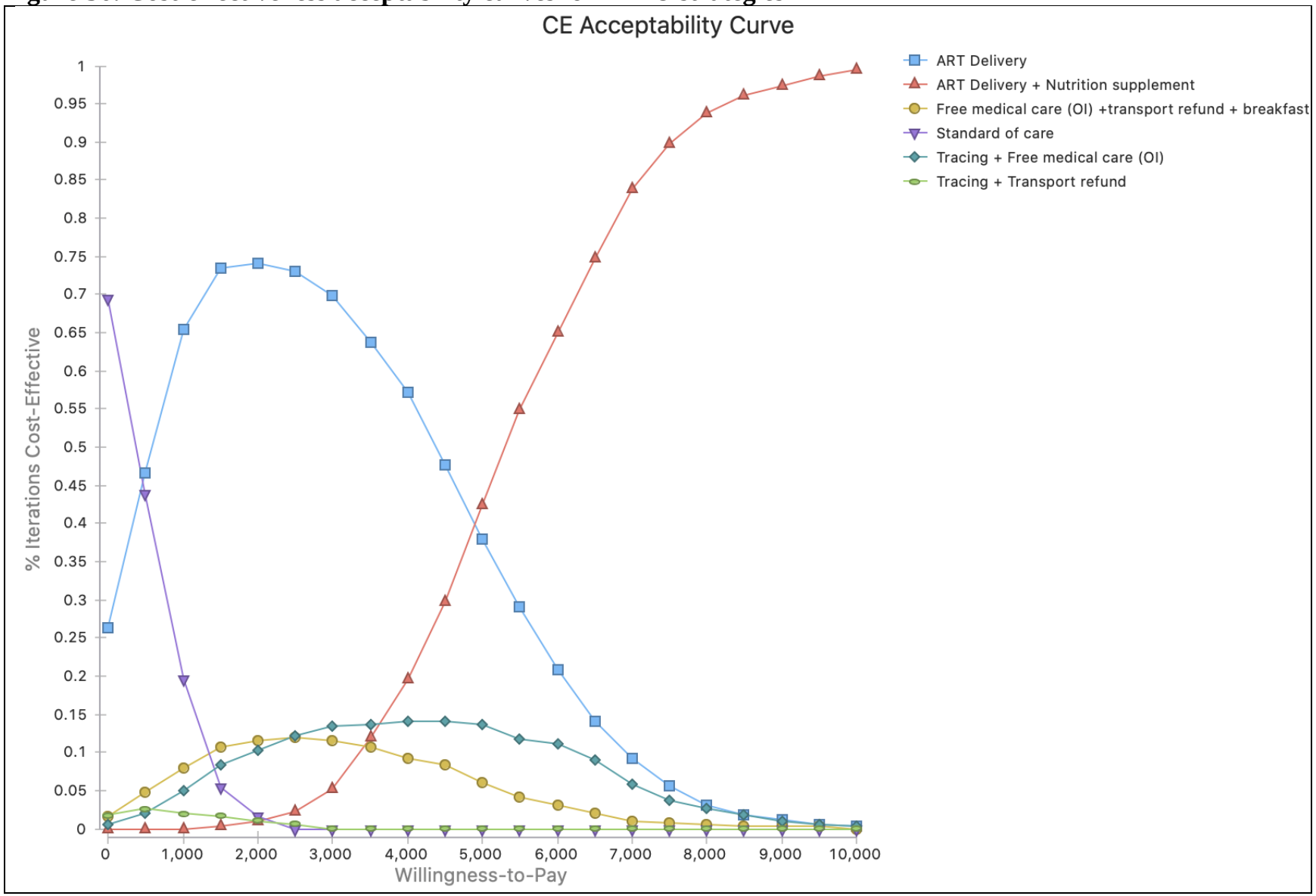


Table S22: Cost-effectiveness results when we assume nutrition supplement is offered for only 10 years

Strategy	Cost	Incremental cost	DALYs Lost	DALYs Averted	ICER
No Intervention	$ 2,994.56		11.52		
ART delivery	$ 3,460.73	$ 466.17	10.55	0.98	$ 470
Tracing + Transport	$ 4,386.60	--	11.05		abs. dominated
Medical care + Transport + Breakfast	$ 4,606.21	--	10.51		ext. dominated
Tracing + Medical care	$ 5,173.28	--	10.35		ext. dominated
ART delivery + Nutrition	$ 6,354.00	$ 2,893.00	10.12	0.42	$ 6,880

Abbreviations: ART = Antiretroviral Therapy; DALYs = Disability Adjusted Life Years; ICER = Incremental cost-effectiveness ratio

Figure S6: Cost-effectiveness acceptability curves for LTFU strategies



References

1. World Health Organization. Making Choices in Health: WHO Guide to Cost-Effectiveness Analysis.; 2003.
2. Chen W, Qian L, Shi J, Franklin M. Comparing performance between log-binomial and robust Poisson regression models for estimating risk ratios under model misspecification. BMC Medical Research Methodology. 2018;18(1):1-12. doi:10.1186/s12874-018-0519-5
3. Williamson T, Eliasziw M, Fick GH. Log-binomial models: exploring failed convergence. Emerging Themes in Epidemiology. 2013;10(14):1-10. http://www.ete-online.com/content/10/1/14.
4. Gregori D, Petrinco M, Bo S, Desideri A, Merletti F, Pagano E. Regression models for analyzing costs and their determinants in health care: An introductory review. International Journal for Quality in Health Care. 2011;23(3):331-341.
5. Neumann PJ, Russell LB, Siegel JE, et al. Using Cost-Effectiveness Analysis in Health and Medicine: Experiences since the Original Panel. In: Cost-Effectiveness in Health and Medicine. 2nd ed. New York: Oxford University Press; 2016. doi:10.1093/acprof:oso/9780190492939.003.0001
6. Dunn A, Grosse SD, Zuvekas SH. Adjusting Health Expenditures for Inflation: A Review of Measures for Health Services Research in the United States. Health Services Research. 2018;53(1):175-196. doi:10.1111/1475-6773.12612
7. Jamison DT, Gelband H, Horton S, et al. Disease Control Priorities: Improving Health and Reducing Poverty. Disease Control Priorities (Third Edition), Volume 9. Washington, DC; 2018. doi:10.1596/978-1-4648-0527-1. License: Creative Commons Attribution CC BY 3.0 IGO
8. Zhang J, Yu KF. What's the relative risk? A method of correcting the odds ratio in cohort studies of common outcomes. Journal of the American Medical Association. 1998;280(19):1690-1691.
9. McNutt LA, Wu C, Xue X, Hafner JP. Estimating the relative risk in cohort studies and clinical trials of common outcomes. American Journal of Epidemiology. 2003;157(10):940-943. doi:10.1093/aje/kwg074
10. Greenland S. Interpretation and choice of effect measures in epidemiologic analyses. American Journal of Epidemiology. 1987;125(5):761-768. doi:10.1093/oxfordjournals.aje.a114593
11. Marschner IC. Relative Risk Regression for Binary Outcomes: Methods and Recommendations. Australian and New Zealand Journal of Statistics. 2015;57(4):437-462. doi:10.1111/anzs.12131
12. Deddens J, Petersen MR, Lei X. Estimation of prevalence ratios when PROC GENMOD does not converge. Proceedings of the 28th Annual SAS Users Group International Conference. 2003:270–28. http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Estimation+of+prevalence+ratios+when+PROC+GENMOD+does+not+converge#0.

13. Petersen MR, Deddens JA. A revised SAS macro for maximum likelihood estimation of prevalence ratios using the COPY method. Occupational and Environmental Medicine. 2009;66(9):639. doi:10.1136/oem.2008.043018

14. Zou G. A Modified Poisson Regression Approach to Prospective Studies with Binary Data. American Journal of Epidemiology. 2004;159(7):702-706. doi:10.1093/aje/kwh090

15. Gail MH, Wieand S, Piantadosi S. Biased estimates of treatment effect in randomized experi- ments with nonlinear regressions and omitted covariates. Biometrika. 1984;71(3):431-444.

16. Polsky D, Glick H. Costing and Cost Analysis in Randomised Trials: Caveat Emptor. Pharmacoeconomics. 2009;27(3):179-188. doi:10.1016/j.neuroimage.2013.08.045.The

17. Mannning WG, Mullahy J. Estimating log models: to transform or not to transform? Journal of Health Economics. 2001;20(2001):461-494. http://portal3.tcu.gov.br/portal/pls/portal/docs/2686925.PDF.

18. Barber J, Thompson S. Multiple regression of cost data: Use of generalised linear models. Journal of Health Services Research and Policy. 2004;9(4):197-204. doi:10.1258/1355819042250249

19. Pregibon D. Goodness of Link Tests for Generalized Linear Models. Journal of the Royal Statistical Society Series C (Applied Statistics). 1980;29(1):15-23.

20. Glick HA, Jalpa A. Doshi, Sonnad SS, Polsky D. Economic Evaluation in Clinical Trials. 2n Edition. New York, NY: Oxford University Press; 2015.

21. Teklehaimanot HD, Teklehaimanot A, Yohannes M, Biratu D. Factors influencing the uptake of voluntary HIV counseling and testing in rural Ethiopia: A cross sectional study. BMC Public Health. 2016;16(1):1-13. doi:10.1186/s12889-016-2918-z

22. Hensen B, Lewis JJ, Schaap A, et al. Factors Associated with HIV-Testing and Acceptance of an Offer of Home-Based Testing by Men in Rural Zambia. AIDS and Behavior. 2015;19(3):492-504. doi:10.1007/s10461-014-0866-0

23. De Allegri M, Agier I, Tiendrebeogo J, et al. Factors affecting the uptake of HIV testing among men: A mixed-methods study in rural Burkina Faso. PLoS ONE. 2015;10(7):1-15. doi:10.1371/journal.pone.0130216

24. Staveteig S, Head SK, Croft TN, Kampa KT. Factors associated with prior testing among HIV-positive adults in sub-Saharan Africa. DHS Comparative Reports. 2016;(43):xi-pp. http://dhsprogram.com/pubs/pdf/CR43/CR43.pdf.

25. Kelvin E, Mwai E, Romo M, et al. Evaluating Oral HIV Self-Testing to Increase HIV Testing Uptake among Truck Drivers in Kenya.; 2017. http://www.3ieimpact.org/media/filer_public/2017/07/19/ie64-truck-drivers-kenya.pdf.

26. George G, Chetty T, Strauss M, et al. Costing analysis of an SMS-based intervention to promote HIV self-testing amongst truckers and sex workers in Kenya. PLoS ONE. 2018;13(7):1-16.

27. Iyer P, Mwai D, N 'ganga A. Costing Kenya'S Current and Proposed Hiv Testing and Counseling Algorithms. Health Policy Project. 2012;(March). https://www.healthpolicyproject.com/pubs/183_KenyaAlgorithms.pdf.

28. Cherutich P, Farquhar C, Wamuti B, et al. HIV partner services in Kenya: a cost and budget impact analysis study. BMC Health Services Research. 2018;18(1):1-11.

29. Eaton JW, Menzies NA, Stover J, et al. Health benefits, costs, and cost-effectiveness of earlier eligibility for adult antiretroviral therapy and expanded treatment coverage: A combined analysis of 12 mathematical models. The Lancet Global Health. 2014;2(1). doi:10.1016/S2214-109X(13)70172-4

30. Smith JA, Sharma M, Levin C, et al. Cost-effectiveness of community-based strategies to strengthen the continuum of HIV care in rural South Africa: A health economic modelling analysis. The Lancet HIV. 2015;2(4):e159-e168. doi:10.1016/S2352-3018(15)00016-8

31. Siebert U, Alagoz O, Bayoumi AM, et al. State-transition modeling: A report of the ISPOR-SMDM modeling good research practices task force-3. Medical Decision Making. 2012;32(5):690-700. doi:10.1177/0272989X12455463

32. Ying R, Sharma M, Celum C, et al. Home HIV testing and counseling for reducing HIV incidence in a generalized epidemic setting: a mathematical modeling analysis. lancent HIV. 2016;3(6):275-282. doi:10.1016/S2352-3018(16)30009-1

33. Beyene MB, Beyene HB. Predictors of late HIV diagnosis among adult people living with HIV/AIDS who undertake an initial CD4 T Cell evaluation, northern Ethiopia: A case-control study. PLoS ONE. 2015;10(10):1-12. doi:10.1371/journal.pone.0140004

34. Belay H, Alemseged F, Angesom T, Hintsa S, Abay M. Effect of late HIV diagnosis on HIV-related mortality among adults in general hospitals of Central Zone Tigray, northern Ethiopia: A retrospective cohort study. HIV/AIDS - Research and Palliative Care. 2017;9:187-192. doi:10.2147/HIV.S141895

35. Sharma M, Ying R, Tarr G, Barnabas R, Division ID, Hutchinson F. A systematic review and meta-analysis of community and facility-based approaches to address gaps in HIV testing and linkage in sub-Saharan Africa. Nature. 2015;528(7580):S77-S85. doi:10.1038/nature16044.A

36. Clinton Health Access Initiative, (CHAI). 2017 Antiretroviral (ARV) Chai Reference Price List.; 2017. https://clintonhealthaccess.org/content/uploads/2017/12/2017-CHAI-ARV-Reference-Price-List_FINAL.pdf.

37. Murray M, Cattamanchi A, Denkinger C, Van'T Hoog A, Pai M, Dowdy D. Cost-effectiveness of triage testing for facility-based systematic screening of tuberculosis among Ugandan adults. BMJ Global Health. 2016;1(2):1-8. doi:10.1136/bmjgh-2016-000064

38. Moodley N, Gray G, Bertram M. The Price of Prevention: Cost Effectiveness of Biomedical HIV Prevention Strategies in

South Africa. Clinical research in HIV/AIDS. 2016;3(1):1-31. http://www.ncbi.nlm.nih.gov/pubmed/28824960%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC5562157.

39. Jacobsen MM, Walensky RP. Modeling and Cost-Effectiveness in HIV Prevention. Current HIV/AIDS Reports. 2016;13(1):64-75. doi:10.1007/s11904-016-0303-2

40. Graves N, McKinnon L, Reeves M, Scuffham P, Gordon L, Eakin E. Cost-effectiveness analyses and modelling the lifetime costs and benefits of health-behaviour interventions. Chronic Illness. 2006;2(2):97-107. doi:10.1179/174592006X110978

41. World Health Organization (WHO). HIV Testing Services: WHO Consolidated Guidelines.; 2015.

42. World Health Organization. Consolidated Guidelines on the Use of Antiretroviral Drugs for Treating and Preventing HIV Infection: Recommendations for a Public Health Approach.; 2016. doi:10.1016/j.jped.2014.04.007

43. Ortblad K, Musoke DK, Ngabirano T, Oldenburg C, Bärnighausen T. Direct Provision versus Facility Collection of HIV Tests: Impacts of Self-Testing among Female Sex Workers in Uganda.; 2018.

44. Severens JL, Milne RJ, Severens H. Discounting health outcomes in economic evaluation: The ongoing debate. Value in Health. 2004;7(4):397-401. doi:10.1111/j.1524-4733.2004.74002.x

45. Salomon JA, Haagsma JA, Davis A, et al. Disability weights for the Global Burden of Disease 2013 study. The Lancet Global Health. 2015;3(11):e712-e723.

46. Harklerode R, Waruiru W, Humwa F, et al. Epidemiological profile of individuals diagnosed with HIV: results from the preliminary phase of case-based surveillance in Kenya. AIDS care. 2020;32(1):43-49. doi:10.1080/09540121.2019.1612021.Epidemiological

47. Badri M, Lawn SD, Wood R. Short-term risk of AIDS or death in people infected with HIV-1 before antiretroviral therapy in South Africa: a longitudinal study. Lancet. 2006;368(9543):1254-1259. doi:10.1016/S0140-6736(06)69117-4

48. Reniers G, Slaymaker E, Nakiyingi-Miiro J, et al. Mortality trends in the era of antiretroviral therapy: Evidence from the network for analysing longitudinal population based HIV/AIDS data on Africa (ALPHA). AIDS. 2014;28:S533-S542. doi:10.1097/QAD.0000000000000496

49. Kasamba I, Baisley K, Mayanja BN, Maher D, Grosskurth H. The impact of antiretroviral treatment on mortality trends of HIV-positive adults in rural Uganda: A longitudinal population-based study, 1999-2009. Tropical Medicine and International Health. 2012;17(8). doi:10.1111/j.1365-3156.2012.02841.x

50. Badri M, Bekker L, Orrell C, Pitt J, Wood R. Initiating highly active antiretroviral therapy in sub- Saharan Africa : an assessment of the revised World Health Organization scaling-up guidelines. Aids. 2004;(December 2003). doi:10.1097/01.aids.0000125941.58195.95

51. Mills EJ, Bakanda C, Birungi J, et al. Male gender predicts mortality in a large cohort of patients receiving antiretroviral therapy in Uganda. Journal of the International AIDS Society. 2011;14(1):52. doi:10.1186/1758-2652-14-52

52. Hawkins C, Hertzmark E, Spiegelman D, et al. Switching to second-line ART in relation to mortality in a large Tanzanian HIV cohort. Journal of Antimicrobial Chemotherapy. 2017;72(7):2060-2068. doi:10.1093/jac/dkx098

53. World Health Organization (WHO). GHO | By category | Life tables by country - Kenya. https://apps.who.int/gho/data/view.main.60850?lang=en. Published 2015. Accessed October 22, 2020.

54. Sharma M, Barnabas R V., Celum C. Community-based strategies to strengthen men's engagement in the HIV care cascade in sub-Saharan Africa. PLoS Medicine. 2017;14(4):1-13. doi:10.1371/journal.pmed.1002262

55. UNAIDS. Blind Spot: Reaching out to Men and Boys - Addressing a Blind Spot in the Response to HIV.; 2017. https://www.unaids.org/sites/default/files/media_asset/blind_spot_en.pdf.

56. Lalla-Edward ST, Matthew P, Hankins CA, Venter WDF, Gomez GB. Healthcare for truck drivers: Assessing accessibility and appropriateness of South African Roadside Wellness Centres. Journal of Transport and Health. 2018;8(January):63-72.

57. Deuba K, Sapkota D, Shrestha U, et al. Effectiveness of interventions for changing HIV related risk behaviours among key populations in low-income setting: A Meta-Analysis, 2001–2016. Scientific Reports. 2020;10(1):1-13. doi:10.1038/s41598-020-58767-0

58. Kelvin EA, George G, Kinyanjui S, et al. Announcing the availability of oral HIV self-test kits via text message to increase HIV testing among hard-to-reach truckers in Kenya: a randomized controlled trial. BMC Public Health. 2019;19(1):1-7.

59. Lalla-Edward ST, Fischer AE, Venter WDF, et al. Cross-sectional study of the health of southern African truck drivers. BMJ Open. 2019;9(10):1-11.

60. Fobosi SC, Lalla-Edward ST, Ncube S, et al. Access to and utilisation of healthcare services by sex workers at truck-stop clinics in South Africa: A case study. South African Medical Journal. 2017;107(11):994-999. doi:10.7196/SAMJ.2017.v107i11.12379

61. Lalla-Edward ST, Ncube S, Matthew P, Hankins CA, Venter WDF, Gomez GB. Uptake of health services among truck drivers in South Africa: Analysis of routine data from nine roadside wellness centres. BMC Health Services Research. 2017;17(1):1-9.

62. UNAIDS. People Aged 50 Years and Older.; 2014.

63. Ngugi AK, Agoi F, Mahoney MR, et al. Utilization of health services in a resourcelimited rural area in Kenya: Prevalence and associated household-level factors. PLoS ONE. 2017;12(2):1-12. doi:10.1371/journal.pone.0172728

64. Negin J, Nemser B, Cumming R, Lelerai E, Amor Y Ben, Pronyk P. HIV attitudes, awareness and testing among older adults in Africa. AIDS and Behavior. 2012;16(1):63-68. doi:10.1007/s10461-011-9994-y

65. Lafort Y, Lessitala F, Candrinho B, et al. Barriers to HIV and sexual and reproductive health care for female sex workers in Tete, Mozambique: Results from a cross-sectional survey and focus group discussions. BMC Public Health. 2016;16(1). doi:10.1186/s12889-016-3305-5

66. Kelvin EA, George G, Mwai E, et al. Offering self-administered oral HIV testing to truck drivers in Kenya to increase testing: a randomized controlled trial. AIDS Care. 2018;30(1):47-55.

67. Ortblad K, Kibuuka Musoke D, Ngabirano T, et al. Direct provision versus facility collection of HIV self-tests among female sex workers in Uganda: A cluster-randomized controlled health systems trial. PLoS Medicine. 2017;14(11):1-24.

68. Masters SH, Agot K, Obonyo B, Napierala Mavedzenge S, Maman S, Thirumurthy H. Promoting Partner Testing and Couples Testing through Secondary Distribution of HIV Self-Tests: A Randomized Clinical Trial. PLoS Medicine. 2016;13(11):1-15. doi:10.1371/journal.pmed.1002166

69. Hlongwa M, Mashamba-Thompson T, Makhunga S, Murararaneza C, Hlongwana K. Men's perspectives on HIV self-testing in sub-Saharan Africa: A systematic review and meta-synthesis. BMC Public Health. 2020;20(1):1-13.

70. Okoboi S, Lazarus O, Castelnuovo B, et al. Peer distribution of HIV self-test kits to men who have sex with men to identify undiagnosed HIV infection in Uganda: A pilot study. PLoS ONE. 2020;15(1):22-28. doi:10.1371/journal.pone.0227741

71. Shava E, Manyake K, Mdluli C, et al. Acceptability of oral HIV self-testing among female sex workers in Gaborone, Botswana. PLoS ONE. 2020;15(7 July):1-11. doi:10.1371/journal.pone.0236052

72. Ortblad KF, Chanda MM, Musoke DK, et al. Acceptability of HIV self-testing to support pre-exposure prophylaxis among female sex workers in Uganda and Zambia: Results from two randomized controlled trials. BMC Infectious Diseases. 2018;18(1):1-8. doi:10.1186/s12879-018-3415-z

73. Napierala S, Desmond NA, Kumwenda MK, et al. HIV self-testing services for female sex workers, Malawi and Zimbabwe. Bulletin of the World Health Organization. 2019;97(11):764-776. doi:10.2471/BLT.18.223560

74. Luseno WK, Wechsberg WM. Correlates of HIV testing among South African women with high sexual and substance-use risk behaviours. AIDS Care - Psychological and Socio-Medical Aspects of AIDS/HIV. 2009;21(2):178-184. doi:10.1080/09540120802017594

75. Aho J, Nguyen VK, Diakité SL, Sow A, Koushik A, Rashed S. High acceptability of HIV voluntary counselling and testing among female sex workers: Impact of individual and social factors. HIV Medicine. 2012;13(3):156-165. doi:10.1111/j.1468-1293.2011.00951.x

76. Tokar A, Broerse JEW, Blanchard J, Roura M. HIV Testing and Counseling Among Female Sex Workers: A Systematic Literature Review. AIDS and Behavior. 2018;22(8):2435-2457. doi:10.1007/s10461-018-2043-3

77. Information regarding the OraQuick In-Home HIV Test | FDA. https://www.fda.gov/vaccines-blood-biologics/approved-blood-products/information-regarding-oraquick-home-hiv-test#res. Accessed October 14, 2020.

78. Nkenfou CN, Kembou JE, Temgoua ES, et al. Evaluation of OraQuick® HIV-1/2 as oral rapid test. African Journal of Infectious Diseases. 2013;7(2):27-30. doi:10.4314/ajid.v7i2.2

79. Kimotho J, Ng'ang'a Z, Nyairo E, et al. Laboratory Evaluation of the Validity of the Current HIV Testing Algorithm in Kenya. American Journal of Internal Medicine. 2015;3(1):23. doi:10.11648/j.ajim.20150301.14

80. Ochako R, Vu L, Peterson K. Insights Into Potential Users and Messaging for HIV Oral Self-Test Kits in Kenya, 3ie Grantee Final Report. Washington, DC. Vol 3ie.; 2014.

81. Thirumurthy H, Masters SH, Mavedzenge SN, Maman S, Omanga E, Agot K. Promoting male partner HIV testing and safer sexual decision making through secondary distribution of self-tests by HIV-negative female sex workers and women receiving antenatal and post-partum care in Kenya: a cohort study. lancent HIV. 2016;3(6):e266-e274. doi:10.1016/S2352-3018(16)00041-2.Promoting

82. Thirumurthy H, Omanga E, Obonyo B, Masters S, Agot K. Using HIV self-testing to promote male partner and couples testing in Kenya, 3ie Impact Evaluation Report 60. International Initiative for Impact Evaluation. 2017;(3ie).

83. Choko AT, MacPherson P, Webb EL, et al. Uptake, Accuracy, Safety, and Linkage into Care over Two Years of Promoting Annual Self-Testing for HIV in Blantyre, Malawi: A Community-Based Prospective Study. PLoS Medicine. 2015;12(9):1-21. doi:10.1371/journal.pmed.1001873

84. National AIDS & STI Control Program M of HK. Guidelines on Use of Antiretroviral Drugs for Treating and Preventing HIV Infection in Kenya 2018 Edition.; 2018.

85. Tymejczyk O, Brazier E, Yiannoutsos CT, et al. Changes in rapid HIV treatment initiation after national "treat all" policy adoption in 6 sub-Saharan African countries: Regression discontinuity analysis. PLoS medicine. 2019;16(6):e1002822. doi:10.1371/journal.pmed.1002822

86. Wekesa P, McLigeyo A, Owuor K, Mwangi J, Nganga E, Masamaro K. Factors associated with 36-month loss to follow-up and mortality outcomes among HIV-infected adults on antiretroviral therapy in Central Kenya. BMC Public Health. 2020;20(1):1-11. doi:10.1186/s12889-020-8426-1

87. Tweya H, Oboho IK, Gugsa ST, et al. Loss to follow-up before and after initiation of antiretroviral therapy in HIV facilities in Lilongwe, Malawi. PLoS ONE. 2018;13(1):1-12. doi:10.1371/journal.pone.0188488

88. Vuylsteke B, Semde G, Auld AF, et al. Retention and risk factors for loss to follow-up of female and male sex workers on antiretroviral treatment in Ivory Coast: a retrospective cohort analysis. J Acquir Immune Defic Syndr. 2015;68 Suppl 2:S99-

S106. doi:10.1097/qai.0000000000000442

89. Brinkhof MWG, Dabis F, Myer L, et al. Early loss of HIV-infected patients on potent antiretroviral therapy programmes in lower-income countries. Bulletin of the World Health Organization. 2008;86(7):559-567. doi:10.2471/BLT.07.044248

90. Nuwagaba-Biribonwoha H, Kiragga AN, Yiannoutsos CT, et al. Adolescent pregnancy at antiretroviral therapy (ART) initiation: a critical barrier to retention on ART. Journal of the International AIDS Society. 2018;21(9):1-9. doi:10.1002/jia2.25178

91. Haas AD, Zaniewski E, Anderegg N, et al. Retention and mortality on antiretroviral therapy in sub-Saharan Africa: Collaborative analyses of HIV treatment programmes: Collaborative. Journal of the International AIDS Society. 2018;21(2):1-7. doi:10.1002/jia2.25084

92. Grimsrud A, Cornell M, Schomaker M, Fox MP. CD4 count at antiretroviral therapy initiation and the risk of loss to follow-up: results from a multicentre cohort study. Journal of Epidemiology and Community Health. 2016;70(6):549-555. doi:10.1136/jech-2015-206629.CD4

93. Johnson LF, Anderegg N, Zaniewski E, et al. Global variations in mortality in adults after initiating antiretroviral treatment: An updated analysis of the International epidemiology Databases to Evaluate AIDS cohort collaboration. Aids. 2019;33(July):S283-S294. doi:10.1097/QAD.0000000000002358

94. Ochieng-Ooko V, Ochieng D, Sidle JE, et al. Influence of gender on loss to follow-up in a large HIV treatment programme in western Kenya. Bulletin of the World Health Organization. 2010;88(9):681-688. doi:10.2471/BLT.09.064329

95. Kiwanuka J, Waila JM, Kahungu MM, Kitonsa J, Kiwanuka N. Determinants of loss to follow-up among HIV positive patients receiving antiretroviral therapy in a test and treat setting: A retrospective cohort study in Masaka, Uganda. PLoS ONE. 2020;15(4):1-17. doi:10.1371/journal.pone.0217606

96. Galárraga O, Wamai RG, Sosa-Rubí SG, et al. HIV prevention costs and their predictors: Evidence from the ORPHEA Project in Kenya. Health Policy and Planning. 2017;32(10):1407-1416. doi:10.1093/heapol/czx121

97. Bautista-Arredondo S, Sosa-Rubi SG, Opuni M, et al. Costs along the service cascades for HIV testing and counselling and prevention of mother-to-child transmission. Aids. 2016;30(16):2495-2504. doi:10.1097/QAD.0000000000001208

98. Sweat M, Gregorich S, Sangiwa G, et al. Cost-effectiveness of voluntary HIV-1 counselling and testing in reducing sexual transmission of HIV-1 in Kenya and Tanzania. Lancet. 2000;356(9224):113-121. doi:10.1016/S0140-6736(00)02447-8

99. Obure CD, Vassall A, Michaels C, et al. Optimising the cost and delivery of HIV counselling and testing services in Kenya and Swaziland. Sexually Transmitted Infections. 2012;88(7):498-503. doi:10.1136/sextrans-2012-050544

100. U.S. Centers for Disease Control and Kenyan Ministry of Health. The Cost of Comprehensive HIV Treatment in Kenya: Report

of a Cost Study of HIV Treatment Programs in Kenya. Atlanta, GA (USA) and Nairobi, Kenya; 2013.

101. Parks R. The Rise, Critique and Persistence of the DALY in Global Health. The Journal of Global Health. 2014:1-9.
102. Mboup A, Béhanzin L, Guédou FA, et al. Early antiretroviral therapy and daily pre-exposure prophylaxis for HIV prevention among female sex workers in Cotonou, Benin: a prospective observational demonstration study. Journal of the International AIDS Society. 2018;21(11):1-11. doi:10.1002/jia2.25208
103. Baeten JM, Heffron R, Kidoguchi L, et al. Integrated Delivery of Antiretroviral Treatment and Pre-exposure Prophylaxis to HIV-1–Serodiscordant Couples: A Prospective Implementation Study in Kenya and Uganda. PLoS Medicine. 2016;13(8):1-17. doi:10.1371/journal.pmed.1002099
104. Eakle R, Gomez garriel B, Naicker N. HIV pre-exposure prophylaxis and early antiretroviral treatment among female sex workers in South Africa: Results from a prospective observational demonstration project. PLoS Medicine. 2017;14(11):1-17. doi:10.1371/journal.pmed.1002444
105. Grant RM, Lama JR, Anderson PL, McMahan V, Liu AY, Vargas L. Preexposure Chemoprophylaxis for HIV Prevention in Men Who Have Sex with Men. The new engl and journal o f medicine. 2010;363(27):2587-2599.
106. Baeten JM, Donnell D, Ndase P, et al. Antiretroviral prophylaxis for HIV prevention in heterosexual men and women. New England Journal of Medicine. 2012;367(5):399-410. doi:10.1056/NEJMoa1108524
107. Choopanya K, Martin M, Suntharasamai P, et al. Antiretroviral prophylaxis for HIV infection in injecting drug users in Bangkok, Thailand (the Bangkok Tenofovir Study): A randomised, double-blind, placebo-controlled phase 3 trial. The Lancet. 2013;381(9883):2083-2090. doi:10.1016/S0140-6736(13)61127-7
108. Thigpen MC, Kebaabetswe PM, Paxton LA, et al. Antiretroviral preexposure prophylaxis for heterosexual HIV transmission in Botswana. New England Journal of Medicine. 2012;367(5):423-434. doi:10.1056/NEJMoa1110711
109. Heestermans T, Browne JL, Aitken SC, Vervoort SC, Klipstein-Grobusch K. Determinants of adherence to antiretroviral therapy among HIV-positive adults in sub-Saharan Africa: A systematic review. BMJ Global Health. 2016;1(4):1-13. doi:10.1136/bmjgh-2016-000125
110. Hanscom B, Janes HE, Guarino PD, Huang Y, Brown ER. Preventing HIV-1 Infection in Women using Oral Pre-Exposure Prophylaxis: A Meta-analysis of Current Evidence. J Acquir Immune Defic Syndr. 2016;73(5):606-608. doi:10.1016/j.physbeh.2017.03.040
111. Kim SH, Gerver SM, Fidler S, Ward H. Adherence to antiretroviral therapy in adolescents living with HIV: Systematic review and meta-analysis. Aids. 2014;28(13):1945-1956. doi:10.1097/QAD.0000000000000316
112. Machado DM, De AM, Carvalho S, Riera R. Adolescent pre-exposure prophylaxis for HIV prevention: current perspectives.

Adolescent Health, Medicine and Therapeutics. 2017;8:137-148. doi:10.2147/IJWH.S113675

113. Pellowski JA, Price DM, Harrison AD, et al. A Systematic Review and Meta-analysis of Antiretroviral Therapy (ART) Adherence Interventions for Women Living with HIV. AIDS and Behavior. 2019;23(8):1998-2013. doi:10.1007/s10461-018-2341-9

114. Mutua G, Sanders E, Mugo P, et al. Safety and adherence to intermittent pre-exposure prophylaxis (PrEP) for HIV-1 in African men who have sex with men and female sex workers. PloS one. 2012;7(4). doi:10.1371/journal.pone.0033103

115. Soomro N, Fitzgerald G, Seeley J, Schatz E, Nachega JB, Negin J. Comparison of Antiretroviral Therapy Adherence Among HIV-Infected Older Adults with Younger Adults in Africa: Systematic Review and Meta-analysis. AIDS and Behavior. 2019;23(2):445-458. doi:10.1007/s10461-018-2196-0

116. Marrazzo J, Ramjee G, Richardson BA, et al. Tenofovir-based Oral PrEP Prevents HIV Infection among Women. N Engl J Med. 2015;372(1):509-518. doi:10.1097/COH.0000000000000207.Tenofovir-based

117. Hermann K, Van Damme W, Pariyo GW, et al. Community health workers for ART in sub-Saharan Africa: Learning from experience - Capitalizing on new opportunities. Human Resources for Health. 2009;7:1-11. doi:10.1186/1478-4491-7-31

118. Fatti G, Meintjes G, Shea J, Eley B, Grimwood A. Improved survival and antiretroviral treatment outcomes in adults receiving community-based adherence support: 5-year results from a multicentre cohort study in South Africa. Journal of Acquired Immune Deficiency Syndromes. 2012;61(4):50-58. doi:10.1097/QAI.0b013e31826a6aee

119. Taylor C, Griffiths F, Lilford R. Affordability of comprehensive community health worker programmes in rural sub-Saharan Africa. BMJ Global Health. 2017;2(3):1-7. doi:10.1136/bmjgh-2017-000391

120. Ormel H, Kok M, Kane S, et al. Salaried and voluntary community health workers: Exploring how incentives and expectation gaps influence motivation. Human Resources for Health. 2019;17(1):1-12. doi:10.1186/s12960-019-0387-z

121. Fatti G, Jackson D, Goga AE, et al. The effectiveness and cost-effectiveness of community-based support for adolescents receiving antiretroviral treatment: An operational research study in South Africa. Journal of the International AIDS Society. 2018;21:23-34. doi:10.1002/jia2.25041

122. Rosen S, Ketlhapile M. Cost of using a patient tracer to reduce loss to follow-up and ascertain patient status in a large antiretroviral therapy program in Johannesburg, South Africa. Tropical Medicine and International Health. 2010;15(SUPPL. 1):98-104. doi:10.1111/j.1365-3156.2010.02512.x

123. Rich ML, Miller AC, Niyigena P, et al. Excellent clinical outcomes and high retention in care among adults in a community-based HIV treatment program in rural rwanda. Journal of Acquired Immune Deficiency Syndromes. 2012;59(3):35-42. doi:10.1097/QAI.0b013e31824476c4

124. Stella-Talisuna A, Bilcke J, Colebunders R, Beutels P. Cost-effectiveness of socioeconomic support as part of HIV care for the poor in an urban community-based antiretroviral program in Uganda. Journal of Acquired Immune Deficiency Syndromes. 2014;67(2):e76-e83. doi:10.1097/QAI.0000000000000280

125. Benzekri NA, Sambou JF, Tamba IT, et al. Nutrition support for HIV-TB co-infected adults in Senegal, West Africa: A randomized pilot implementation study. PLoS ONE. 2019;14(7):1-13. doi:10.1371/journal.pone.0219118

126. Posse M, Baltussen R. Costs of providing food assistance to HIV/AIDS patients in Sofala province, Mozambique: A retrospective analysis. Cost Effectiveness and Resource Allocation. 2013;11(1):1-7. doi:10.1186/1478-7547-11-20

127. Losina E, Touré H, Uhler LM, et al. Cost-effectiveness of preventing loss to follow-up in HIV treatment programs: A Côte d'Ivoire appraisal. PLoS Medicine. 2009;6(10). doi:10.1371/journal.pmed.1000173

128. Vu L, Waliggo S, Zieman B, et al. Annual cost of antiretroviral therapy among three service delivery models in Uganda. Journal of the International AIDS Society. 2016;19(Suppl 4):1-7. doi:10.7448/IAS.19.5.20840

129. Moreland S, Namisango E, Paxton A, Powell RA. The Costs of HIV Treatment, Care, and Support Services in Uganda.; 2013.

130. Shade SB, Osmand T, Luo A, et al. Costs of streamlined HIV care delivery in rural Ugandan and Kenyan clinics in the SEARCH Study. Aids. 2018;32(15):2179-2188. doi:10.1097/QAD.0000000000001958

131. Tagar E, Sundaram M, Condliffe K, et al. Multi-Country analysis of treatment costs for HIV/AIDS (match): Facility-level art unit cost analysis in Ethiopia, Malawi, Rwanda, South Africa and Zambia. PLoS ONE. 2014;9(11). doi:10.1371/journal.pone.0108304

132. Marseille E, Giganti MJ, Mwango A, et al. Taking ART to Scale: Determinants of the Cost and Cost-Effectiveness of Antiretroviral Therapy in 45 Clinical Sites in Zambia. PLoS ONE. 2012;7(12). doi:10.1371/journal.pone.0051993

133. Kouanda S, Bocoum FY, Doulougou B, et al. User fees and access to ARV treatment for persons living with HIV/AIDS: Implementation and challenges in Burkina Faso, a limited-resource country. AIDS Care - Psychological and Socio-Medical Aspects of AIDS/HIV. 2010;22(9):1146-1152. doi:10.1080/09540121003605047

134. Long L, Brennan A, Fox MP, et al. Treatment outcomes and cost-effectiveness of shifting management of stable ART patients to nurses in South Africa: An observational cohort. PLoS Medicine. 2011;8(7). doi:10.1371/journal.pmed.1001055

135. Mikkelsen E, Hontelez JAC, Nonvignon J, et al. The costs of HIV treatment and care in Ghana. Aids. 2017;31(16):2279-2286. doi:10.1097/QAD.0000000000001612

136. Apanga S, Punguyire D, Adjei G. Estimating the cost to rural ambulating HIV/AIDS patients on Highly Active Antiretroviral Therapy (HAART) in rural Ghana: a pilot study. Pan African Medical Journal. 2012;8688:1-6.

137. Chimbindi N, Bor J, Newell M-L, et al. Time and money: the true costs of health care utilization for patients receiving 'free'

HIV/TB care and treatment in rural KwaZulu-Natal. J Acquir Immune Defic Syndr. 2015;70(October 1):e52-e60. doi:10.1097/QAI.0000000000000728.Time

138. Namey E, Perry B, Headley J, et al. Understanding the financial lives of female sex workers in Abidjan, Côte d'Ivoire: implications for economic strengthening interventions for HIV prevention. AIDS Care - Psychological and Socio-Medical Aspects of AIDS/HIV. 2018;30:6-17. doi:10.1080/09540121.2018.1479031

139. Hoffmann CJ, Milovanovic M, Kinghorn A, et al. Value stream mapping to characterize value and waste associated with accessing HIV care in South Africa. PLoS ONE. 2018;13(7):1-10. doi:10.1371/journal.pone.0201032

140. Tuller DM, Bangsberg DR, Senkungu J, Ware NC, Emenyonu N, Weiser SD. Transportation costs impede sustained adherence and access to HAART in a clinic population in Southwestern Uganda: A qualitative study. AIDS and Behavior. 2010;14(4):778-784. doi:10.1007/s10461-009-9533-2

141. Bergmann JN, Wanyenze RK, Stockman JK. The cost of accessing infant HIV medications and health services in Uganda. AIDS Care - Psychological and Socio-Medical Aspects of AIDS/HIV. 2017;29(11):1426-1432. doi:10.1080/09540121.2017.1330531

142. Medecins Sans Frontieres. Untangling the Web of Antiretroviral Price Reductions.; 2016.

Vita

Deo Mujwara was born on June 16, 1986, in Fort Portal, Uganda. He received his Bachelors of science in Quantitative Economics from Makerere University (Kampala, Uganda) in 2011 and worked for Uganda Bureau of Statistics and Stanbic Bank Uganda before enrolling for his Masters of Arts in Economics at Georgia State University (Atlanta, Georgia) in 2013. After completing his Masters in 2015, Deo worked for Dekalb County Housing Authority as a research assistant for a year. In 2016, he joined the Healthcare Policy and Research Ph.D. program in the Department of Health Behavior and Policy at Virginia Commonwealth University School of Medicine. During the Ph.D. program, he conducted research under the supervision of Dr. April D. Kimmel focusing on access to HIV care and application of mathematical modeling techniques to inform efficient policy decisions. Through collaborations with faculty and fellow students, he worked on various manuscripts and presented his research at peer-reviewed conferences. He currently works as a health economist at Allelica, a company committed to reducing the impact of chronic diseases through genomic medicine. As a health economist, he develops mathematical models to examine the cost-effectiveness of polygenic risk scores in disease prevention.

Publications

Kimmel AD, Bono RS, Keiser O, Sinayobye JD, Estill J, **Mujwara D**, Tymejczyk O, Nash D. Mathematical modeling to inform Treat All implementation in sub-Saharan Africa: a scoping review. J Virus Eradication 2018;4 (Suppl 2):47–54. 2018

Deo Mujwara, Geoffrey Henno, Stephen T Vernon, Siyang Peng, Paolo Di Domenico, Brock Schroeder, George B. Busby, Gemma A Figtree, Giordano Bottà. Integrating a Polygenic Risk Score for Coronary Artery Disease as a Risk Enhancing Factor in the Pooled Cohort Equation is Cost-effective in a US Health System. Journal of American College of Cardiology (Review)