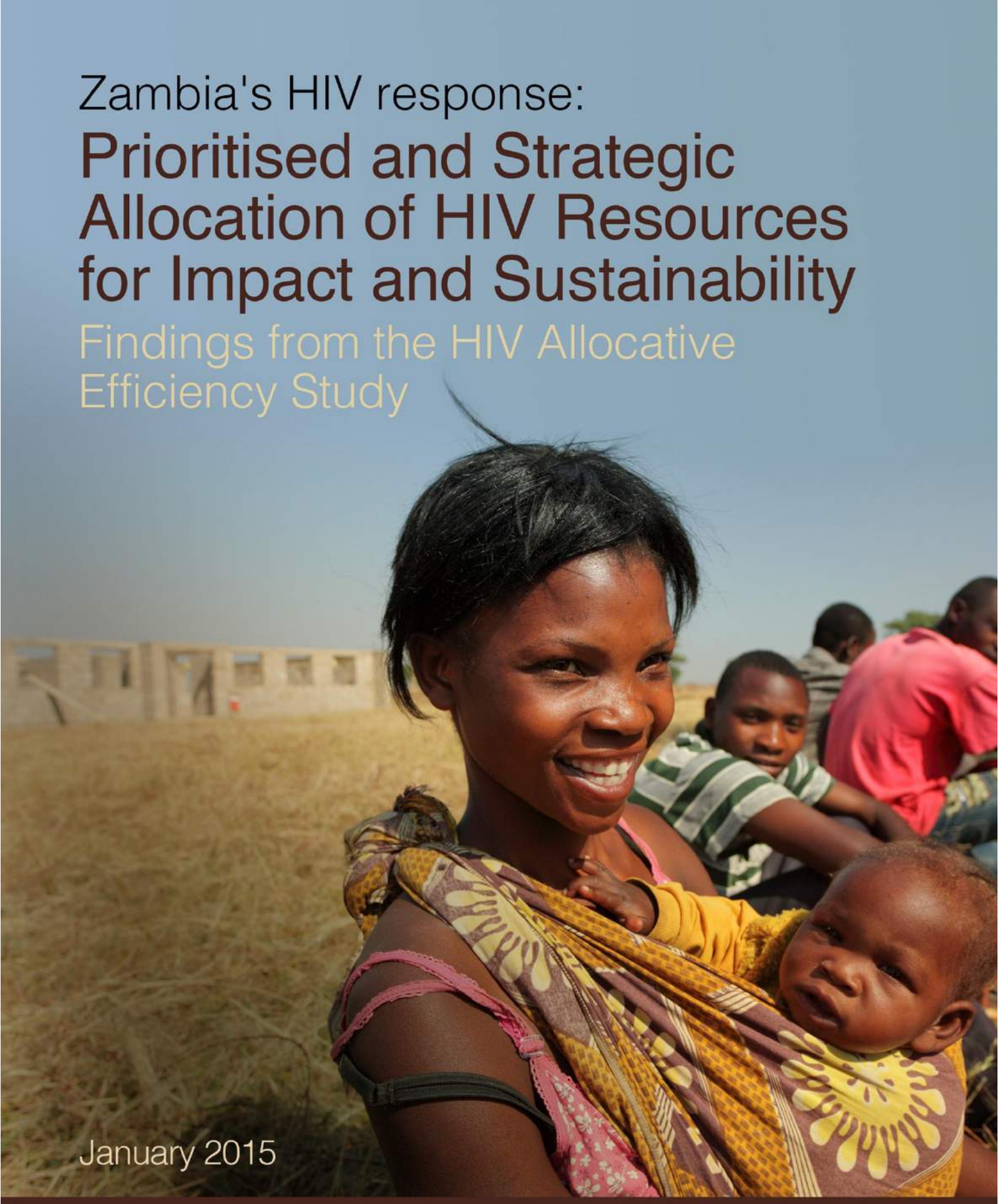
Zambia's HIV response:

Prioritised and Strategic Allocation of HIV Resources for Impact and Sustainability

Findings from the HIV Allocative Efficiency Study



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Zambia's HIV response:
Prioritised and strategic allocation of HIV resources for impact and sustainability

Findings from the HIV allocative efficiency study

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Abbreviations

AIDS	Acquired immunodeficiency syndrome
ANC	Antenatal care
ART	Antiretroviral therapy
ARV	Antiretroviral
BCC	Behaviour change communication
CHAI	Clinton Health Access Initiative
CPI	Consumer price index
DALY	Disability-adjusted life year
DATF	District AIDS task force
DHS	Demographic and health survey
eMTCT	Elimination of mother-to-child transmission
FSW	Female sex worker
GARPR	Global AIDS Response Progress Report
GBD	Global burden of disease
GDP	Gross domestic product
HCT	HIV counselling and testing
HIV	Human immunodeficiency virus
IHME	Institute for Health Metrics and Evaluation
LIC	Low-income country
LMIC	Low- and middle-income country
MCH	Maternal and child health
MSM	Men having sex with men
MTCT	Mother-to-child transmission
NCD	Non-communicable disease
NHA	National health accounts
NASF	National AIDS strategic framework
PEPFAR	U.S. President's Emergency Plan for AIDS Relief
PICT	Provider-initiated counselling and testing
PLHIV	People living with HIV
PWID	People who inject drugs
PMTCT	Prevention of mother-to-child transmission
R-NASF	Revised national AIDS strategic framework
SRH	Sexual and reproductive health
STI	Sexually transmitted infection
TasP	Treatment as prevention
TB	Tuberculosis
UNAIDS	Joint UN Programme on AIDS
UNFPA	United Nations Population Fund
UNGASS	United Nations General Assembly Special Session
UNICEF	United Nations Children Fund
UNSW	University of New South Wales
UNZA	University of Zambia
VCT	Voluntary counselling and testing
VMMC	Voluntary medical male circumcision
WHO	World Health Organization
YLL	Years of life lost

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Executive Summary

This report summarises findings from an allocative efficiency and financial commitment analysis conducted for the Government of Zambia by the World Bank and the University of New South Wales. It uses Optima, a mathematical model of HIV transmission and disease progression. Optima is a population-based and flexible model, which provides a formal method of optimisation and determines optimal allocations of HIV resources across numerous HIV programmes, target populations, and funding levels. It also provides epidemic, investment scenario and financial commitment analysis.

Background and context

HIV allocative efficiency studies are generally posing the question "How can HIV funding be optimally allocated to the combination of HIV response interventions that will yield the highest impact?". In this context the government of Zambia approached the World Bank with a request to conduct an allocative efficiency analysis to inform the revised national AIDS strategic framework (R-NASF), prioritisation of the HIV response, and value for money considerations in the context of resource mobilisation. Four main policy questions were posed: (1) What are the estimated and projected HIV epidemic trends until 2030 and the transmission dynamics between sub-populations? (2) What is the optimised HIV resource allocation to minimise HIV incidence and AIDS mortality between 2014 and 2030? (3) What is the minimum spend required to meet moderate or ambitious national strategic impact targets? (4) What are the long-term financial commitments of HIV treatment and healthcare costs?

Zambia, recently reclassified as a low- and middle-income country (LMIC), had an estimated total population of 14.08 million in 2012. The country enjoys positive annual GDP growth—at 6.4% in 2013—and a fairly stable macroeconomic situation. Nevertheless, income levels are highly skewed and in 2010, 60.5% of the population were living below the national poverty line, which impacts negatively on health.

HIV/AIDS remains a public health problem of enormous proportions, joined by several other leading causes of premature death: malaria, lower respiratory infections, diarrhoeal diseases, protein-energy malnutrition and meningitis. Also, Zambia is experiencing a steady increase of non-communicable diseases. Already in 2008, overweight/obesity was at 39% in Lusaka District, hypertension at 13%, and diabetes at 4%. The health sector has tried hard to achieve results, and the Zambia DHS 2013–14 found increased use of modern family planning methods, decreased prevalence of children left out completely from the essential immunisation programme, more widespread use of insecticide treated nets among children under five and pregnant women,

increased use of antenatal care services, and increased child delivery at health facilities. Fertility is reported to be declining and estimated neonatal, infant and under five mortality is decreased. These wider changes in the health sector have a great influence on how the HIV response can best be provided so that it harnesses synergies and provides best value for money.

In order to conduct the modelling analysis, Optima was populated with demographic, epidemiological, sexual behaviour, service use and programme coverage data, as well as economic, financial and cost information. The model was calibrated against the best available measured HIV prevalence and antiretroviral treatment (ART) coverage data, and the relationship between expenditure and outcomes was established for the mathematical optimisation process.

HIV epidemic trends

The Zambia epidemic is characterised by high HIV prevalence and low male circumcision levels (ZDHS 2007 reporting adult HIV prevalence of 14.3%). Both Optima and Spectrum predict slowly decreasing HIV prevalence levels. Using the available data on population sizes, demographic growth and HIV infection data, the Optima model projected about 60,000 new HIV infections per year post-2015 until 2030. Much of the historical reduction in new infections stems from the large fall in vertical transmission over the past decade. Optima also compared the number of infections transmitted by each of the defined sub-populations, and the number of infections acquired. Female sex workers, men having sex with men and males in the general adult population of all ages showed up as *net transmitting* populations. In contrast, all female populations except FSW are *net receivers*, hence receiving more infections than transmitting.

Financing and implementation of the HIV response

The per capita health expenditure in 2012 was US$96. Zambia has been one of the key beneficiaries of development assistance for the national HIV response, receiving relatively high levels of financial assistance compared to the national HIV/AIDS burden. Much of this assistance has been provided in the years prior to Zambia gaining LMIC status, which happened in 2012. The assistance plays an important role in funding health and HIV programmes in Zambia—in 2012, nearly 45% of total external aid disbursed was for health and HIV.

Total HIV spending for Zambia in 2012 was approximately US$283 million which increased from US$269 million in 2011. The costs of the national HIV response were equivalent to almost 7% of overall government expenditures in 2012. The bulk of HIV funding came from external sources (93% of the total HIV expenditure), and the rest came from the government and private sources.

Spending on ART significantly increased from US$ 23 million in 2005 to US$ 125 million in 2012, while other programmes remained relatively constant except for the growing voluntary medical male circumcision (VMMC) programme. The spending on ART, VMMC and prevention for key

populations is largely funded by external sources. In 2012, PEPFAR spent 48% of their US$204 million on treatment and US$4.6 million on VMMC, which accounts for 96% of total spending on treatment and 78% of total VMMC spending in Zambia. Indirect costs and critical enablers consumed about 30% of total resources spent on Zambia's HIV response. Progress in individual programmes can be summarised as follows:

ART: As of December 2013, the number of people receiving ART in accordance with the national treatment protocol was 580,118 (81.9% coverage, UNGASS 2014 report). The percentage of ART clients known to be on treatment 12 months after initiation has increased to 81% in December 2013. The AIDS death rate among adults has reduced by two-thirds from 1.02% in 2002 to 0.34% in 2011, and among infants by over three-quarters from 1.51% in 1997 to 0.33% in 2011, largely due to the scale-up of the prevention of mother-to-child transmission (PMTCT) programme.

VMMC: By end 2013, Zambia had reached 33% of the internationally defined 80% coverage target. The VMMC scale-up, started in 2008 (2,758 VMMCs), has seen steep increases in the number of procedures ever since, reaching 294,466 VMMCs in 2013 and a cumulative total 2008–13 of 635,458. Although there has been a rapid increase in the number of annual VMMC procedures, the figures have fallen short of annual targets.

PMTCT: In 2013, 75,165 women out of an estimated 77,772 (97%) received antiretrovirals to reduce the risk of mother-to-child transmission, and almost three-quarters of HIV exposed infants were tested for HIV within 2 months of birth. These efforts have translated into a drop in the estimated HIV transmission rate from mother to child from 24% in 2009 to 12% in 2012. The successful scale-up of PMTCT goes hand in hand with the further increased uptake of ANC services from 94% in 2007 to the near-universal level of 96% in 2013–14 (DHS data).

HIV counselling and testing (HCT): In 2013, 2,066,216 adults received HCT services and obtained their results. More women had used HCT services than men. There is an urgent need to understand what proportion of PLHIV know their HIV positive status.

Condoms and education on risk reduction: Condoms have wide availability, also as a family planning tool. However, low and inconsistent use of male and female condoms remains a challenge despite significant efforts to encourage people to take control of their sexual and reproductive health. The level of unprotected sexual intercourse is also reflected in the large burden of curable sexually transmitted infections in Zambia, accounting for about 10% of out-patient visits.

Services for key populations at high risk of HIV: The review did not identify recent data on access of FSW and MSM to HIV services. Activities relating to sex work, same sex relationships, and injecting drug use are illegal in Zambia. Laws against same-sex behaviour, drug use and sex work have been shown to increase HIV vulnerability and create barriers to service access, while also undermining basic human rights. Children are a particularly vulnerable group where 9% of 10–19

year olds had reported having traded sex for food or money. In the UNGASS NCPI rating, the score for human rights has continued its downward trend decreasing from a score of 7 in 2007 to a score of 1 in 2013.

Optimal resource allocation

The detailed methodology of the Optima modelling, the parameters and limitations of the analysis are presented in the report and a technical appendix. Here, we only summarise the investment cascade to minimise both HIV incidence and AIDS deaths by 2030:

- Should less than 70% of current (i.e., estimated 2013) funding be available, funding should be prioritised to the ART programme and to some PMTCT programme activities, in order to continue providing treatment to the maximum number of ART clients and prevent AIDS death, and prevent vertical HIV transmissions.
- If between 70% and 100% of current funding is available, PMTCT should be scaled-up and then ART provision should be expanded with HCT services getting more funding to diagnose additional PLHIV to support the ART expansion.
- As more funding than the current funding is available, the two proven interventions VMMC and FSW HIV prevention programmes (including ART for FSW) should be introduced, followed by consolidation and further scale-up of ART and the commencement of scale-up of BCC and condom programmes for adults.
- Each of these HIV programmes, including adult BCC and condom programmes, should then be scaled up further as more resources - above 160% of current funding - become available, as it is the adult population where there is a high number of new infections, but also advanced infections which require prevention and treatment interventions.
- Only at funding levels above 200% of current funding, do youth condom and BCC programmes become a priority. The youth also gain important and sustained HIV prevention benefits from the VMMC programme (VMMC uptake is across Southern Africa highest in adolescent boys and young men), and HIV positive youth gain treatment benefits through ART. Due to the small population size and small estimated contribution to overall incidence, MSM programmes are of less importance for minimizing incidence and deaths within Zambia as a whole (but are a key target for health service promotion and human rights support).
- Projecting HIV impact over 30 years to 2044 (instead of to 2030) illustrates the importance of VMMC investment to reduce the HIV epidemic in a sustainable, long-term manner.

Costs to achieve national strategy targets

We estimated resource needs to achieve moderate and ambitious targets by 2030 as per the R-NASF (see footnote 2 for definitions of targets). Both scenarios require an increase in annual spending—the moderate targets 1.4 times current[1] spending, and the ambitious targets 2.5 times current spending. However, improvements in technical efficiency and economies of scale could reduce indirect costs and the overall amount of funding required. By increasing spending to achieve the moderate objectives by 2030, 220,000 more HIV infections, 60,000 more deaths, and 20,000 more mother-to-child transmissions could be averted in Zambia. By increasing spending to achieve the ambitious objectives by 2030, 460,000 more HIV infections, 104,000 more deaths, and 35,000 more mother-to-child transmissions could be averted in Zambia.

Conclusions

On the HIV epidemic and scale-up of programmes

- **The HIV epidemic has consolidated at a high level.** Burden of disease estimates show that AIDS was the leading cause of premature death in Zambia in 2010. The toll is enormous in people aged 20–50 years, where one in every two years of life lost is due to HIV.
- **The number of new HIV infections is projected to stabilise,** however, there is much uncertainty in epidemic projections until the DHS 2013–14 data can be used to update the projections. With the available epidemiological data, Spectrum and Optima project a levelling off of new HIV infections at approximately 60,000 per year until 2030.
- FSW and MSM have, according to Optima outputs, high HIV incidence rates at 4.0% and 2.5%, respectively, but these estimates lack recent empirical data points. The forthcoming survey data from Panos and Population Council will help to appropriately model these key populations' epidemics and plan targeted service delivery.
- **A key prevention success is the decrease in vertical transmission.** Optima estimates over 25,000 mother-to-child transmissions in 2000, and only about 4,000 in 2013, a reduction of approximately 85%. In 2013, 72% of infants born to HIV positive mothers received a virological test for HIV within 2 months of birth.
- The national VMMC programme has been rolled out, stimulated innovation in service delivery, and now needs to catch up to meet coverage and impact targets.
- **Zambia's health providers have succeeded at bringing the services closer to the people.**

[1] We use the term "current" spending to denote the estimated baseline funding level used in this analysis, which is based on 2012 NASA data and PEPFAR/CHAI data on ART spend. It amounts to US$ 413 million.

By 2012, there were 564 ART sites, 287 VMMC sites and 1,800 HCT sites. Service decentralisation translates into decreased opportunity costs for clients, as documented in the assessment of health facility performance by the Institute for Health Metrics and Evaluation (IHME) and the University of Zambia (UNZA).

- As the ART programme evolves further and the B+ PMTCT option is being planned, piloted and seeing early implementation, understanding non-adherence to ART is crucial to make ART investments work. There is research evidence that clinic-based food assistance for ART clients improves ART adherence.
- The IHME/UNZA efficiency assessment concluded that efficiency gains may be possible and needed as the ART programme expansion continues. The same study found that ART patient volumes could significantly increase given facility resources—that Zambia has the potential to increase its average annual ART patient volume by 117%. This means that the marginal cost of additional ART patients may be lower, and that more health impact may be gained with limited additional resources.

On optimisation of HIV resource allocation

- Our optimisation analysis found that ART, PMTCT and VMMC are the most important programmes (with HCT supporting ART) for greater health impact. In a time horizon until 2030, ART tended to dominate the optimal allocation scenarios for both HIV incidence and AIDS death reductions. ART's immediacy of health impact is compelling; however, further scale-up will face multiple challenges of affording second line treatment (approximately US$580 instead of $280 for first line), long-term medication adherence, and healthcare costs accruing in the aging ART cohort.
- **In a time horizon of 30 years to 2044, VMMC is an even more desirable investment as its prevention impact is better captured.** Combined with the evidence that VMMC brings males to use HIV services and chiefly contributes to men's HIV testing, STI screening, and linkage to care statistics, investment in VMMC scale-up is expected to provide sustained direct and indirect health impact.
- FSW-oriented programmes, targeted at this population with high HIV incidence and insufficient HIV service coverage, remain important. They should receive approximately two (2) of every 100 HIV dollars at current HIV funding levels, so that reach can be increased and very high levels of condom use achieved in paid sex. MSM programmes did not show up as a priority investment in the optimisation due to the small size of the MSM population. This does however not mean that specialised providers should not offer high quality adapted services for this vulnerable and underserved key population.

- **There should be little change in allocations to HCT,** which is required to identify PLHIV in need of ART, and to the PMTCT programme, which is responsible for the large drop in MTCT and uses a relatively small proportion of the HIV response budget while maintaining the low level of MTCT.
- Optimisation of resources to achieve R-NASF targets[2] suggested that the MTCT reduction target would probably be achieved first and at least cost, followed by the AIDS death reduction target. The overall HIV incidence reduction target appeared hardest and most costly to achieve. Ballpark figures are an annual total cost of US$ 600 million for meeting the moderate target and over US$ 1 billion annually to achieve the ambitious target.
- One interesting finding of the Optima analysis was also that Zambia's HIV resource allocation pattern in 2012/13 may have been close to optimal for best HIV incidence reductions in a 15-year time frame (but not for AIDS death reductions, and not over longer time horizons of analysis, where higher investment in VMMC would have been more impactful).
- **Therefore, ART, PMTCT, HCT and VMMC must be the core programmes of a high-impact HIV response.** Treatment not only saves lives and restores health and productivity, but is also one of the few prevention approaches with effectiveness to reduce population-level transmission, if high levels of viral suppression are achieved.

On HIV financing and sustainability of the HIV response

- **The HIV response consumes about one (1) of every 5 health dollars**. A continuous dialogue on how Zambia can develop domestic HIV funding streams while improving HIV programme performance is essential, as the dependency on external funding is exceptionally high (in 2012, 93% of response funding was covered by external sources).
- The government policies of free access to HIV prevention and AIDS care and treatment mean that Zambians have financial protection from the potentially catastrophic medical costs associated with HIV and AIDS.
- **A large part of future spending commitments up to 2030 is determined by existing HIV infections.** It is only post-2025 that the projected costs of existing HIV infections start to fall substantially, due to mortality among PLHIV. Projected total annual commitment peaks at nearly US$ 300 million in about 2018 and remains at nearly US$ 250 million per year by

[2] Moderate: Reduce new infections by at least 21%, AIDS deaths by at least 14%, new MTCT by at least 7% between 2014-2030; Ambitious: Reduce new infections by at least 45%, AIDS deaths by at least 29%, new MTCT by at least 40% between 2014-2030.

2030, according to Optima projections.

- It is estimated that currently annual health care and treatment costs amount to about 0.6–0.7% of GDP, and that this percentage will fall to approximately 0.3% of GDP by 2030.
- Even moderate R-NASF targets (reducing new infections by at least 21%, AIDS deaths by at least 14%, and MTCT by at least 7% over 2014–30) would require substantial additional expenditure of the order of magnitude of US$ 20 million per year**. This emphasises the need for considerable and sustained HIV investment in Zambia's efforts to prevent HIV infection and AIDS mortality.**
- A very large proportion of the total HIV response budget is spent on management and administration of the HIV response, and the proportion has increased recently (from 26% in 2010 to 35% in 2012). **Efficiency gains would free up resources which could be used elsewhere, increase health production and make Zambia's HIV response more sustainable.** The country has evidence from efficiency assessments where savings could potentially be made, for instance in the reduction of facility cost per ART visit**. Reducing programme management costs by 20% and reinvesting these savings in priority HIV programmes could prevent 139,000 additional HIV infections until 2030.** This would correspond to a 12% reduction in new infections compared to current spending allocations.

How Zambia's HIV response can be improved in the future

This report has specifically identified five areas in which the HIV response can be improved:

1 **Improve the technical efficiency and reach of HIV programmes**: Technical efficiency gains would free up resources which could be used elsewhere, increase health production and make Zambia's HIV response more sustainable. The country has evidence from efficiency assessments where savings could potentially be made, for instance in the reduction of facility cost per ART visit. The IHME/UNZA efficiency assessment found that many facilities had additional unused capacity for ART clients, and concluded that "health facilities are positioned to support Zambia's goal of providing universal access to HIV treatment and care". Furthermore, a very large proportion of the total HIV response budget is spent on management and administration of the HIV response (over a third in last NASA year). We estimated that reducing programme management costs by 20% and reinvesting these savings in priority HIV programmes could prevent 139,000 additional HIV infections until 2030. This would correspond to a 12% reduction in new infections compared to current spending allocations.

2 **Allocate resources efficiently to achieve best impact:** ART, PMTCT and VMMC are the most important programmes (with HCT supporting ART) for optimising the impact of current levels of HIV investment in the medium- and long-term. Our analysis of impact of optimal allocations over a 30 years' time horizon confirmed VMMC as an excellent investment with a long-term view of sustained epidemiological impact and a once-off procedure only. ART has a high potential to avert both AIDS deaths and new infections through the TasP effect. A large and maturing ART/TasP programme will require effective client-specific ART adherence interventions, and see healthcare costs accruing in the aging ART cohort.

3 **Mobilise additional domestic resources as economic growth, ability to pay and disease burden allow**: Zambia is in a group of countries with high dependency on external HIV funding—an artefact of Zambia's historical LIC status until 2012. While Zambia's government expenditure on health is relatively higher than in other comparable countries, the domestic HIV spending as a share of total HIV expenditure is very low. In 2012, Zambia received US$ 264 million from external sources for its HIV response (93% of total HIV spend) and contributed itself US$15.8 million according to NASA data. This represents only 1.8% of Zambia's public sector expenditure on health. Considering the economic growth data of Zambia, there is potential to increase the HIV contribution in line with ability to pay and disease burden. A continuous dialogue on how Zambia can develop domestic HIV funding streams while improving HIV programme performance is essential.

4 **Better plan for and predict programme financial sustainability**: Increased domestic financing needs to be provided in sustainable and at predictable levels. At high external dependency levels, it is particularly difficult to predict future funding levels, and this applies to health assistance in general and to HIV specifically. The country would need considerable additional and sustained HIV investment to pursue HIV incidence and AIDS deaths strategic targets. Moderate and ambitious impact scenarios would cost an additional US$ 20 million and US$ 50+ million per year, respectively. A large part of future spending commitments up to 2030 is determined by existing HIV infections. Projected total annual commitment remains at considerable levels throughout this time horizon, peaking at nearly US$ 300 million in about 2018 and remaining at nearly US$ 250 million by 2030, according to Optima projections.

5 **Intensify programmes for key populations at high risk through allocation of additional resources to gain coverage, scale and impact:** FSW-oriented programmes showed up as important in our optimisation analysis and should receive about 2% of current HIV response funding. This makes epidemiological sense as this population has the highest HIV incidence rate and appears to be underserved currently. We conclude that spending on

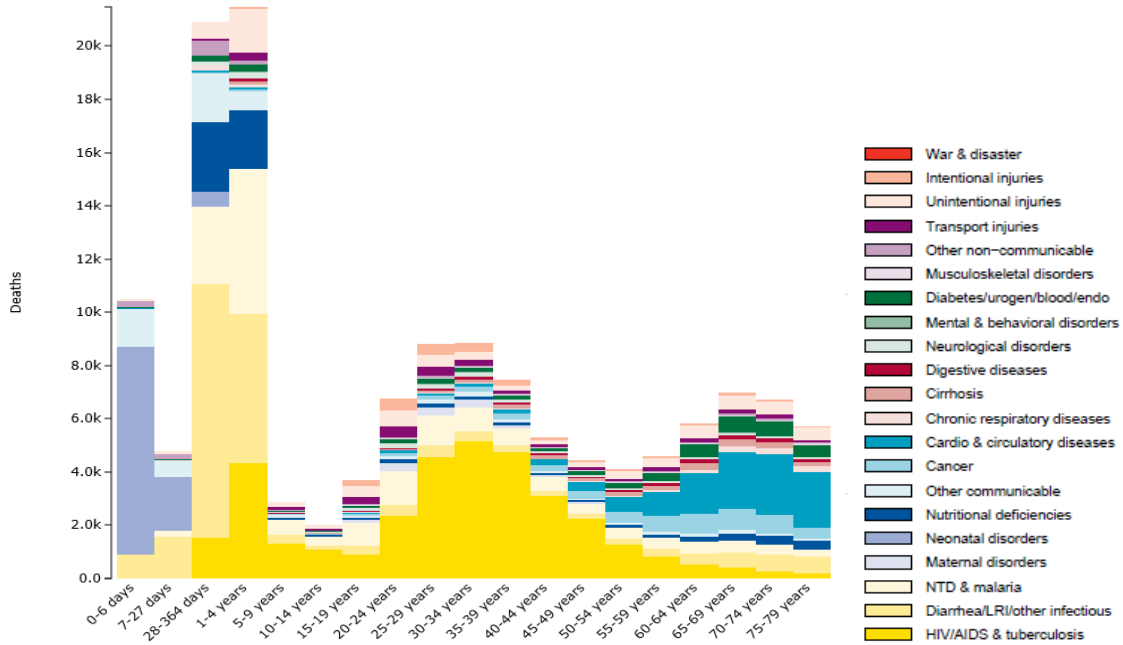
FSW services should be increased until coverage reaches its maximum level and very high levels of condom use are achieved in paid sex. MSM programmes did not show up in the optimisation due to the small size of the MSM population. This does however not mean that specialised providers should not offer high quality adapted services for this vulnerable and underserved key population.

CHAPTER 1. INTRODUCTION

1.1. Context and Purpose of the Report

Zambia was recently reclassified as a LMIC country, and has a total population if 14.08 million (2012 estimate). [1] The country's macro-economy is experiencing stability and positive annual GDP growth at 6.4% in 2013—mostly resource driven and thus subject to the volatility of resource-related growth. [2] Overall, 60.5% of the population are living below the national poverty line (2010 data) and this impacts negatively on health. [3] HIV/AIDS remains a public health problem of enormous proportions. In 2010, HIV/AIDS was responsible for most premature deaths in the country. [4] It is estimated that 20.4% of years of life lost (YLL), or 1.75 million, were due to HIV/AIDS. Another 2.9% of YLL (247,000) were due to TB. **Figure 1** shows cause-specific mortality across age groups.

Figure 1 Causes of death by age group, Zambia (2010*)*



Source: Institute for Health Metrics and Evaluation (IHME). GBD Compare. Seattle, WA: IHME, University of Washington, 2013. Available from http://vizhub.healthdata.org/gbd-compare (accessed 8 Oct 2014)

In addition to HIV/AIDS, there are many competing health and development challenges. Between 1990 and 2010, the other five leading causes of premature death kept their positions (malaria, lower respiratory infections, diarrhoeal diseases, protein-energy malnutrition and meningitis) and were jointly responsible for 37.5% of YLL in 2010. The country has continued to experience outbreaks of typhoid, measles and dysentery in some districts. [5] Also, Zambia is seeing a steady increase of non-communicable diseases (NCDs), namely, hypertension, cardiovascular diseases, diabetes, and cancer. In Lusaka District in 2008, the rate for tobacco

smoking in 2008 was 6.8%, alcohol consumption 20.7%, hypertension 12.5%, impaired glucose levels/diabetes 4.0%, overweight/ obesity 39.3%. [6] The country is vulnerable to natural disasters such as droughts and floods which contribute to high levels of malnutrition in the country.

Health care needs are therefore constantly evolving, and service programming needs to be responsive to remain relevant. The first set findings from the Zambia Demographic and Health Survey (DHS) 2013–14 underscore the changing service use behaviours and health status of the Zambian population. [7] The data suggest increased use of modern family planning methods, decreased prevalence of children left out completely from the essential immunisation programme, more widespread use of insecticide treated nets among children under five and pregnant women, increased use of antenatal care services, and increased child delivery at health facilities. Fertility is reported to be declining, and estimated neonatal, infant and under five mortality is decreased. These wider changes in the health sector have a great influence on how the HIV response can best be provided so that it harnesses synergies and strategically adds value in a system which is constantly grappling with resource constraints.

The national HIV response has been scaled up over almost three decades, after the first case of AIDS was diagnosed in Zambia in 1984. Important successes have been achieved, including high coverage of pregnant mothers in need of prevention of mother-to-child transmission (PMTCT) services, and a continuous expansion of the antiretroviral treatment (ART) programme—partially resulting in declines in new infections amongst young people in urban areas. However, this response has become very costly: in 2012, 15.8% of health spending was for HIV/AIDS. An estimated 93% of the HIV response was financed externally in 2012, which inevitably makes the country's HIV response dependent of the availability of external HIV funding. Such external assistance might be less available in the future given international HIV financing trends and Zambia's newly-acquired status of LMIC. After a decade of unprecedented availability of international HIV funding, it has plateaued and there is in many countries a dialogue happening on how to mobilise domestic resources to sustain the national HIV response] .8 [While every new ART client is proof that the government's scale-up of the ART programme for providing treatment access bears fruit, it also creates every time a long-term treatment and funding commitment for the government.

Therefore, in responses to rising treatment bills and stagnating amounts of financial resources for the HIV response, governments in countries with high HIV burden have begun to determine the best investments into the different HIV programmes and services. [9] At the same time, governments have started to consider the sustainability of their HIV response, and to look at ways to quantify their future HIV resource needs over longer time horizons usually reserved for

national development strategies. Importantly, the future treatment needs of current and future ART clients are to be factored in when assessing such long-term spending needs.

Purpose of the Report: This report summarises findings from an HIV allocative efficiency and financial commitment analysis conducted for the Government of Zambia by the World Bank and the University of New South Wales. It uses the mathematical model developed by these two institutions, called Optima.

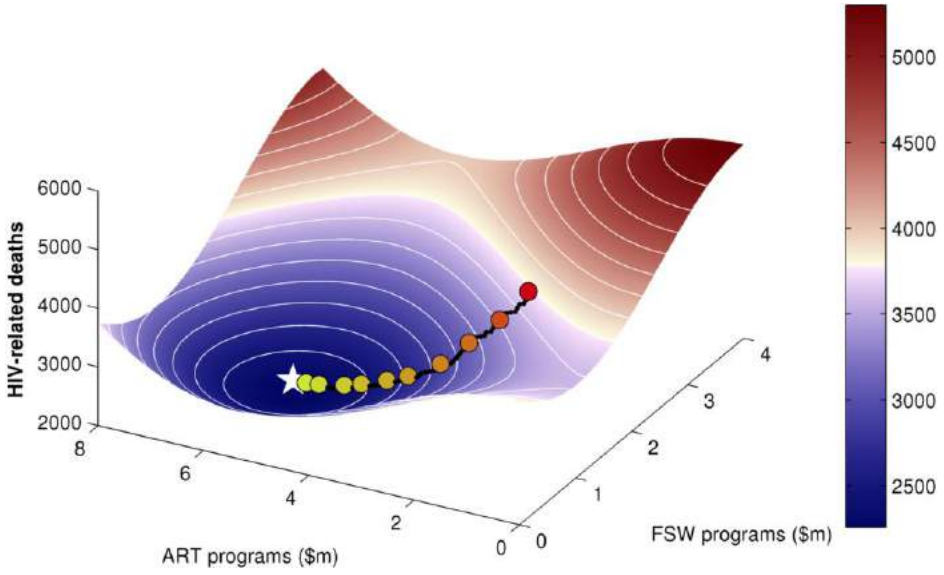
1.2. Optimisation of HIV Resource Allocations in Zambia

Health resources should be allocated in the best possible—or optimal—way to achieve the best possible health outcomes for a country's population. Any consideration of "optimal allocation" is intrinsically linked to a specific outcome that should be achieved through optimisation, and this is further explained herein and in the next section presenting the objectives of this study.

Optima, the software package used in this analysis, addresses practical policy and programme questions encountered by funders, governments, policy makers, health planners, and programme implementers. [10] It is a deterministic mathematical model for HIV optimisation and prioritization. The unique feature of the tool is its *mathematical optimisation algorithm* which helps determine the most efficient resource allocation mix for meeting a certain objective. By using mathematical methods, Optima can determine the optimal allocation of resources across multiple HIV services, over a defined period of time, within a specific funding limitation.

Optima allows users to choose a set of objectives, such as minimising new infections for a given amount of funding, reaching predefined HIV incidence targets for the lowest possible spending, minimising HIV-related deaths, and/or minimising long-term financial commitments, and to then determine the optimal resource allocation for meeting those objectives. The way optimisation works is to try to find the best resource allocation to HIV programmes that achieves the stated objective. **Figure 2** shows the concept schematically with two programmes only. Starting with a current allocation the analysis tries to find the minimum or maximum.

Figure 2 Schematic illustration of optimisation process



Source: UNSW Optima documentation

These optimisations are based on calibrations to epidemiological data; assumptions about the costs of programme implementation and the corresponding coverage levels; and the effects of these programmes on clinical, behavioural, and other epidemiological outcomes. The model uses best-practice HIV epidemic modelling techniques and incorporates realistic biological transmission processes, detailed infection progression stages, sexual mixing patterns, and sexual and HIV service use behaviours.

Optima is also able to calculate allocations of resources that optimally address multiple HIV-related objectives. [10] It can also incorporate different HIV service delivery models, including different unit cost estimates and outcomes of programme coverage levels—potential impacts of technical (programme) efficiency gains can thus be included in analyses. Apart from Optima's key feature (resource optimisation to meet strategic HIV objectives), the tool can also conduct HIV-related financial commitment projections as well as health economic assessments. Optima has already been used in over 20 countries (Kerr et al. submitted).

1.3. Objectives of Analysis

The purpose and objectives of this study were determined through consultation with the Zambian National AIDS Council and other stakeholders. A primary purpose of this work was to provide inputs into the Revised National AIDS Strategic Framework 2014–16 (R-NASF). The overarching objective was to provide the Government of Zambia with an analysis of how allocative efficiency and sustainability of the national HIV response can be improved, and therefore contribute to the Government's continuous drive of prioritising HIV investments.

This included epidemic and optimisation analyses using Optima which:

1. Project the epidemic trends in sub-populations until 2030 and explore the transmission dynamics between sub-populations
2. Determine optimised resource allocation patterns to minimise both cumulative HIV incidence and AIDS mortality between 2014 and 2030
3. Determine minimum spending required to meet moderate or ambitious R-NASF impact targets
4. Project the long-term financial commitment for treatment and healthcare costs of current and expected HIV infections in Zambia

For further details on the optimisation objectives, see section 3.1.

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CHAPTER 2. BACKGROUND

2.1. Historical and Projected Future Trends in the HIV Epidemic in Zambia

In 2013, an estimated 3% of the global number of people living with HIV (PLHIV) were in Zambia, and this was higher than the shares taken by China, Russian Federation or Brazil (each 2%). [11] According to the same UNAIDS report, Zambia contributed about 3% of all new HIV infections estimated to occur globally in 2013, and new HIV infections in Zambia had reduced by 41% between 2005 and 2013.

Zambia has a mature, generalised epidemic in which HIV transmission primarily occurs heterosexually. At the time of this analysis, the last national household level HIV prevalence data were from the ZDHS 2007, with HIV prevalence data awaited from the ZDHS 2013–14. In 2007, 14.3% of adults aged 15–49 were estimated to be HIV positive. For the year 2013, the Spectrum estimate for adult prevalence was 12.6% (GARPR, 2014), which was a modest decrease since the peak in the mid-1990s of about 16%, and Spectrum predicts a further downward sloping trend. Spectrum also estimates a small recent downturn in the number of HIV-infected children aged 0–14 years, after reaching a maximum estimated number of 160,000 in the period of 2005–11 (2013 estimate at 150,000). [12] It is thought that the significant scaling up of the PMTCT programme is preventing vertical HIV transmission while paediatric ART keeps infected children alive, hence the slow decrease in infected child numbers to date.

There are important heterogeneities of HIV prevalence by demographic group, and the Optima modelling in this study took account of these variations. In 2007, a higher proportion of women were living with HIV (16.1%) than men (12.3%) (ZDHS 2007). Prevalence in females was significantly higher than in men at younger ages, and significantly lower at older ages. The differential between female and male prevalence was very large in the age groups 15–19, 20–24, 25–29 and 30–34 years. In the 35–39 year age group, male and female prevalence levels were similar. In the older age groups of 40–44 and 45–49, men had significantly higher HIV prevalence levels than women. Very high HIV prevalence levels have been reported in female sex workers (65%) and men having sex with men (33%) in 2005.

Furthermore, 2007 HIV prevalence levels were also geographically heterogeneous (this was not taken into account in the national-level Optima modelling). Provincial HIV prevalence levels ranged from 7% to 21% in 2007. The Northern and Northwestern Provinces had the lowest HIV prevalence levels at just below 7%. These are areas of low population density, with inhabitants

who are mostly rural and have the highest levels of extreme poverty in the country. However, the discovery and opening up of mines in Northwestern province has significantly increased migration to this province and poses a real risk to increases in new HIV infections in that province. Other co-factors, such as the relatively low proportion of adults reporting multiple partners in Northern Province, and the relatively high male circumcision level in Northwestern Province, also shape the HIV epidemic dynamics. In contrast, Lusaka Province as well as Central Province and the Copperbelt, much more densely populated areas with large urban settlements, had very high HIV prevalence of 17% or above.

HIV prevalence also varied by other characteristics in the ZDHS 2007, for instance: i) Across mobility patterns—for partners, being away from each other poses higher risk for HIV infection; ii) Education levels—men and women with higher education had higher HIV prevalence than those with lower education. Much of these patterns arise through a combination of risk behaviour (including of partners) and access to ART.

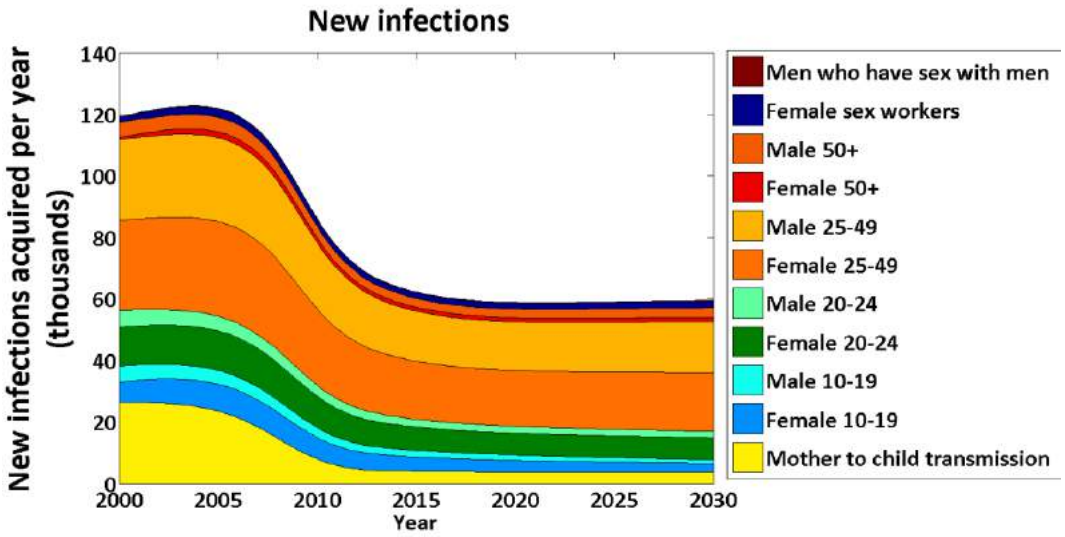
The Optima modelling uses available sexual behaviour and partnership mixing data. It is notable that marriage occurs relatively early in Zambia compared to other countries in the region, at 18.2 years for women and 23.5 years for men.[3] Also, data from the 1996, 2001–02, and 2007 DHS indicate that the median age at first marriage among women has remained constant at 18 years. DHS data suggest that all except a few women and men eventually marry. Less than 2% of women aged 35 and older and less than 1% of men aged 45 and older had never married (ZDHS 2007). Men tend to marry at older ages than women. Marriage and cohabitation are generally considered to be primary indicators of exposure to the risk of pregnancy, however, many women bear children before entering a stable union. Informal relationships are common, and women may have children in the context of such unions. The fertility rate is gradually declining—according to the most recent reports, the total fertility rate has decreased from 6.5 births per woman in 1992 to 5.3 births per woman in 2013–14. [13]

From our Optima model calibration and epidemic projections until 2030, we discern the following epidemiological trends:

- The estimated number of new HIV infections has steeply declined over the last 10 years and is projected to level off in the future—our Optima modelling, using available empirical data until 2007, suggests that HIV transmission has decreased in Zambia, similar to trends estimated by Spectrum (**Figure 3**). Optima estimates about 60,000 new infections per year post-2015. Much of the past reduction in new infections stems from the large fall in vertical transmission over the past decade.

[3] DHS 2007 data, expressing median age at first marriage for women aged 25–49 years and for men aged 25–59 years.

Figure 3 Annual new infections estimated by Optima in Zambia (2000–30)

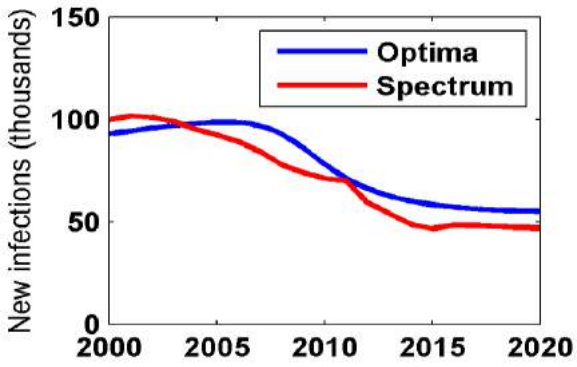


Source: Optima model Zambia, using available demographic, epidemiological and behavioural data.

Comparison between Spectrum-derived and Optima—derived HIV incidence is shown in **Figure 4**, whereas the Optima curve is for individuals aged 10+ years and the Spectrum curve for 15+ years.

The HIV incidence trends broadly agree between the Optima and Spectrum models. Optima concerns ages 10 years and older, Spectrum concerns ages 15 years and older. Optima's HIV incidence peak is estimated to occur a few years later than the incidence peak according to Spectrum. The difference in the age groups for which HIV incidence is modelled partially explains the slight differences in the trends (with Optima capturing HIV incidence in a broader age range).

Figure 4 Comparison between Optima and Spectrum derived annual HIV incidence, Zambia (2000–20)



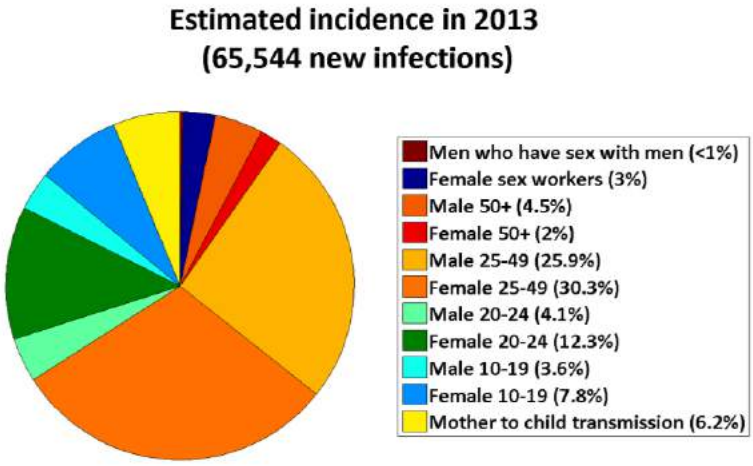
Source: Optima model Zambia, using available demographic, epidemiological and behavioural data and Spectrum outputs (v. 4.69 12 August 2013).

Note: Optima concerns ages 10 years and older; Spectrum concerns ages 15 years and older.

It is estimated that in 2013, the majority of new infections occurred in the 25–49 year old population—Optima estimates a total of 65,544 new HIV infections for 2013, of which about

56% are estimated to have occurred in older adults aged 25–49 years (**Figure 5**). However, a relatively large number of new infections is also estimated for females aged 20–24 years (12%). The absence of recent empirical HIV prevalence data makes this estimation on total and population-specific HIV incidence uncertain. Optima estimates about 4,000 new infections transmitted vertically in 2013. The estimated risk of HIV acquisition in different populations over time is shown in the subsequent **Figure 6**. The small percentage of new infections among men having sex with men (MSM) is in agreement with 2008 estimates with an HIV incidence model, which estimated 732 new infections in MSM for 2008 (or 1% of all new infections) to occur in MSM, and about 40 new infections (0.05% of all new infections) in female partners of MSM.

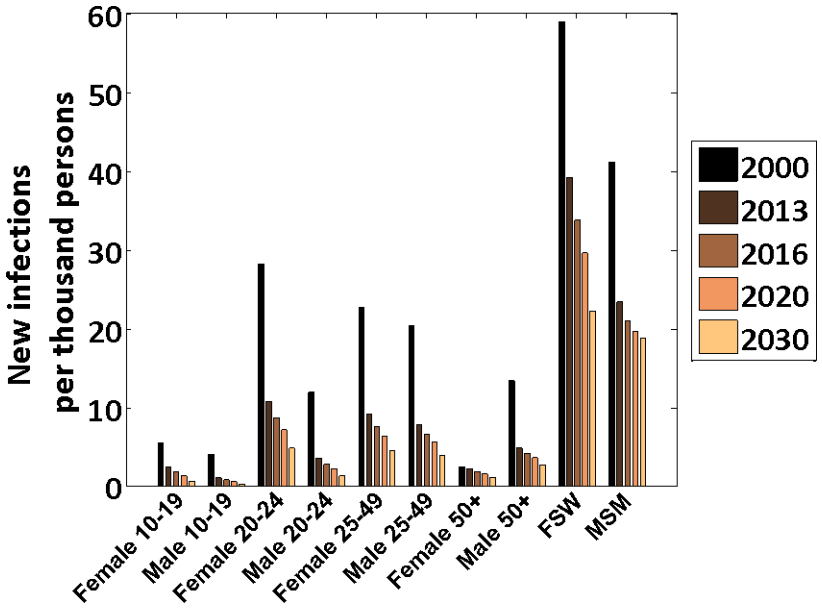
Figure 5 Annual new HIV infections in specific populations in Zambia, estimated by Optima (2013)



Source: Optima model for Zambia, using available demographic, epidemiological and behavioural data.

From modelled data, it seems that estimated HIV incidence has declined in all populations (**Figure 6**). Due to the scarcity of recent empirical HIV data from both general and key populations, these estimations must be seen as very approximate. They suggest very low and decreasing HIV incidence in males below 20, and low and decreasing incidence in females below 20. Over the three DHS rounds with available sexual behaviour data (until 2007), there was a significant fall in the proportion of young females and males aged 15–19 years reporting sex by age 15. Therefore, young people delaying sexual debut and remaining sexually abstinent for longer may play a role in these declining estimated incidence rates in adolescents. Incidence is relatively higher in older females aged 20–24, and males and females aged 25–29, however, trends are also declining. Estimated HIV incidence for female sex workers (FSW) in 2013 is still about 4% (40/1,000), and about 2.5% (25/1,000) for MSM, pointing to these two populations as having highly elevated HIV infection risk.

Figure 6 HIV incidence in specific populations estimated by Optima, Zambia (2000–30)



Source: Optima model Zambia, using available demographic, epidemiological and behavioural data.

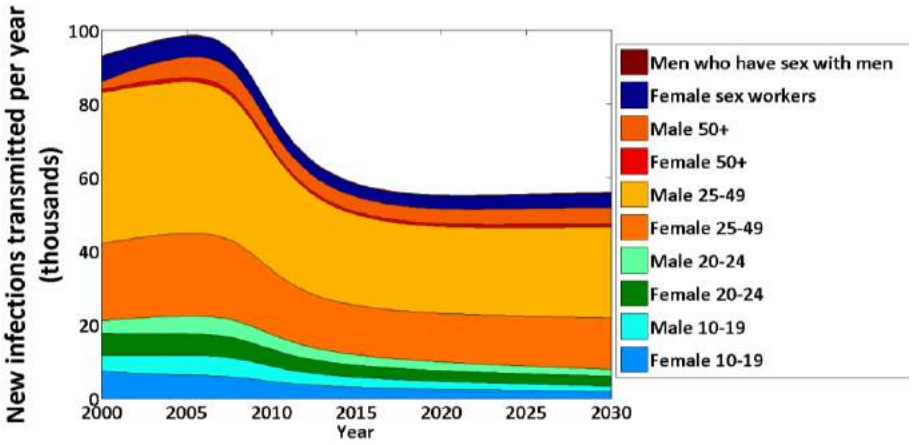
Note: Time intervals between years with estimates vary and go up to 13 years (2000–13); FSW = females sex workers; MSM = men who have sex with men.

The following set of figures explores in more detail Optima's estimated transmission dynamics by population. **Figure 7(A)** shows the estimated number of HIV infections transmitted by the sub- populations, while **Figure 7(B)** shows infections acquired by the same populations.

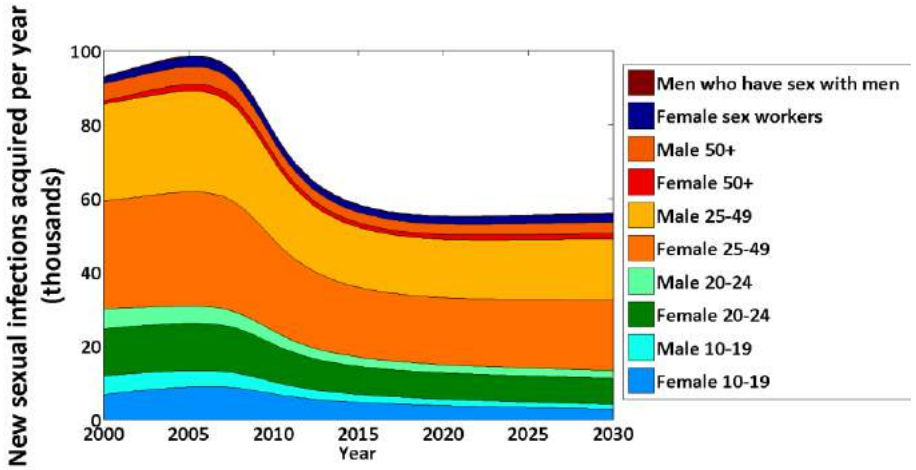
Men aged 25–49 years are consistently estimated to be the population transmitting the most new HIV infections every year, based on the available data. Women aged 25–49 are across the years 2000 to 2030 the population acquiring most new infections, closely followed by men in the same age group. The third most important population for acquiring new infections is females aged 20–24. The shares for 2013 were shown in the previous pie chart (**Figure 5**).

Figure 7 (A) Estimated annual new HIV infections transmitted by HIV–infected individuals aged 10 and above; and (B) Estimated annual new HIV infections acquired in individuals aged 10 years and above, projected by Optima, Zambia 2000–30

(A) New sexual infections transmitted



(B) New sexual infections acquired

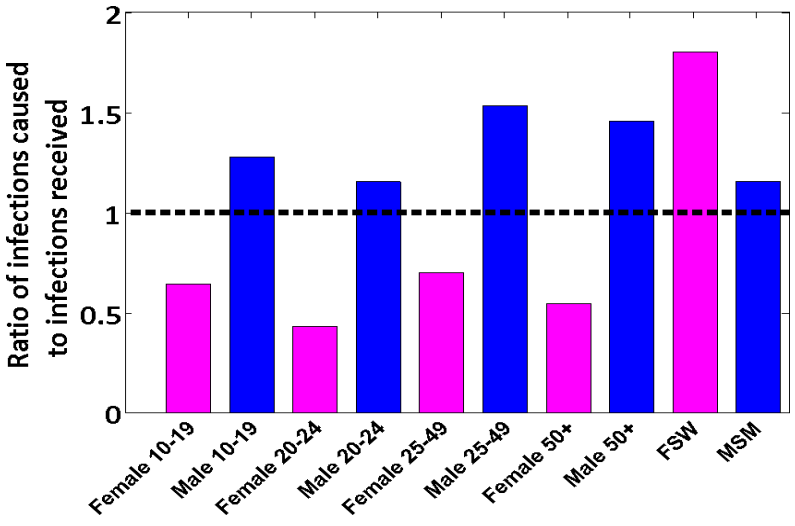


Source: Optima model Zambia, using available demographic, epidemiological and behavioural data

Figure 8 uses the same data by presenting the ratio of HIV infections transmitted to infections acquired for each population for year 2013. A ratio above 1 means that the population is a net transmitting group (in a given year transmitting more new HIV infections than receiving). A ratio below 1 means the population is a net receiver (receiving more new infections than transmitting).

FSW, MSM and males in the general adult population of all ages show up as net transmitting populations. In contrast, all female populations except FSW are net receivers, hence receiving more infections than transmitting. Again, this model estimation is based on a limited amount of actual HIV prevalence data, but it fits with other data on reported sexual behaviour and female susceptibility to HIV infection. For instance, men consistently report a much higher frequency of multiple partnerships than women in Zambia.

Figure 8 Ratios of HIV infections transmitted versus HIV infections acquired across populations, Zambia (2013)



Source: Optima model Zambia, using available demographic, epidemiological and behavioural data.
Note: FSW = females sex workers, MSM = men who have sex with men.

As already pointed out, this modelling of epidemic transmission dynamics in Zambia would benefit greatly from more recent HIV prevalence data, particularly the population–based HIV prevalence data from the 2013–14 DHS, anticipated to be released in the first quarter of 2015. This is especially important as ART roll-out has changed the AIDS-related mortality patterns and the proportion of PLHIV who are virally suppressed through ART and less likely to transmit HIV. The 2013–14 DHS and two ongoing studies in key populations will provide great opportunities to update and refine Zambia's future HIV epidemic trends estimations.

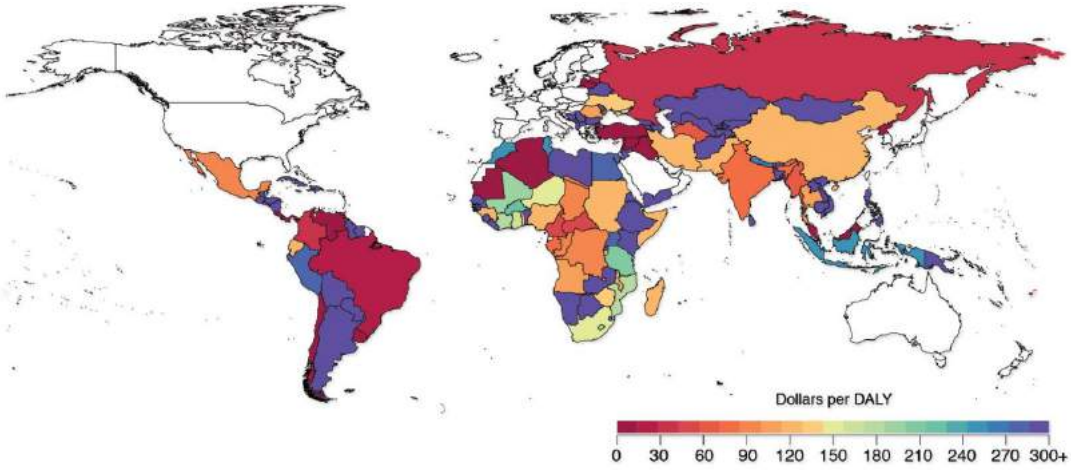
2.2. Financing of the HIV Response

2.2.1 International Comparison of HIV Burden and HIV Assistance

At the international level, Zambia has been one of the key beneficiaries of development assistance for the national HIV response. **Figure 9** illustrates receipt of external assistance per HIV disability-adjusted life year (DALY) across countries, and Zambia is identified as one of the countries receiving relatively high level of assistance compared to the national HIV/AIDS burden (purple colour). Much of this assistance has been provided in the years prior to Zambia gaining LMIC status (which happened in 2012).

A related statistic illustrates that relative to global ranking of countries by the burden of HIV/AIDS (Zambia in 12th place), the country received comparatively high levels of HIV financial assistance (Zambia in 7th place)—**Figure 10**. It should be noted that countries *which make good use of HIV development assistance to reduce AIDS-related mortality and therefore HIV DALYs* may show as receiving disproportionately high development assistance for HIV per HIV DALY.

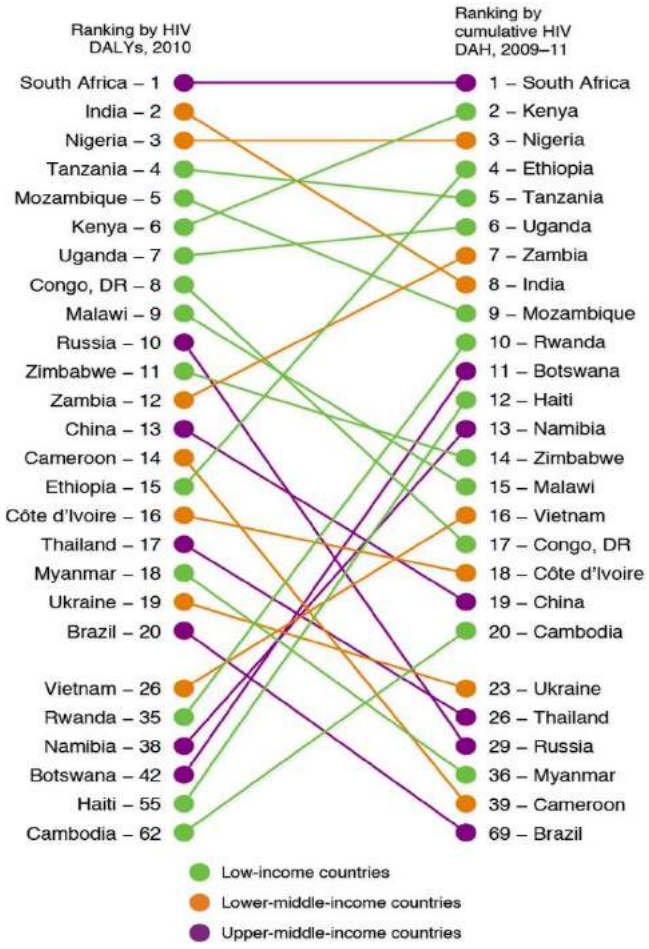
Figure 9 Global comparison of development assistance for HIV 2009–11 per HIV DALYs in 2010



Sources: IHME DAH Database 2013 and Global Burden of Disease Study 2010.

Notes: 2010 DALY estimates are from the Global Burden of Disease Study 2010; Countries that were ineligible for DAH based on their World Bank income classification are shown in white. DAH received is shown in real 2011 US dollars; DAH=Development Assistance for Health.

Figure 10 Top 20 countries by 2010 HIV/AIDS burden of disease versus total 2009–11 HIV external assistance



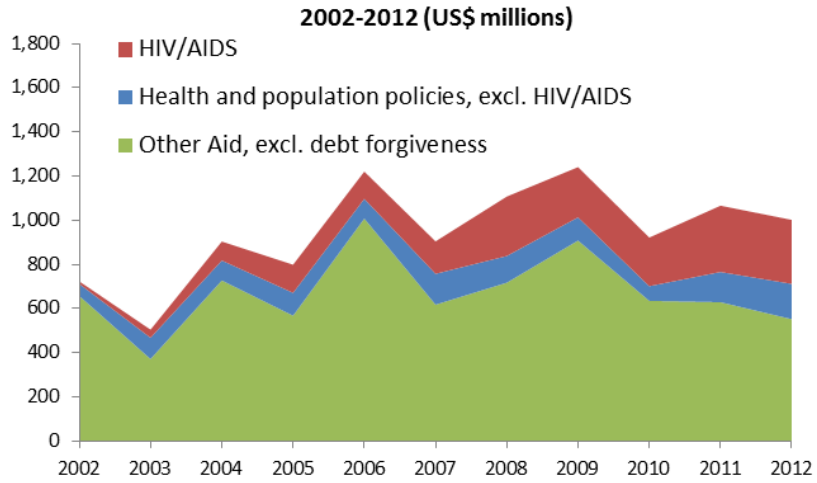
Sources: IHME Database 2013, and Global Burden of Disease Study 2010

2.2.2 Development, health and HIV financing in Zambia

Development financing in Zambia

Despite Zambia's recent LMIC status, official development assistance (ODA) still funds a significant part of the national budget and plays an important role in funding health and HIV programmes in Zambia. However, ODA has seen a downwards trend (as is the expectation for countries who graduate to LMIC status). Nearly 45% of total external aid disbursed was for health and HIV in 2012 (**Figure 11**).

Figure 11 Zambia: Aid disbursements, US$ millions (2002–12)



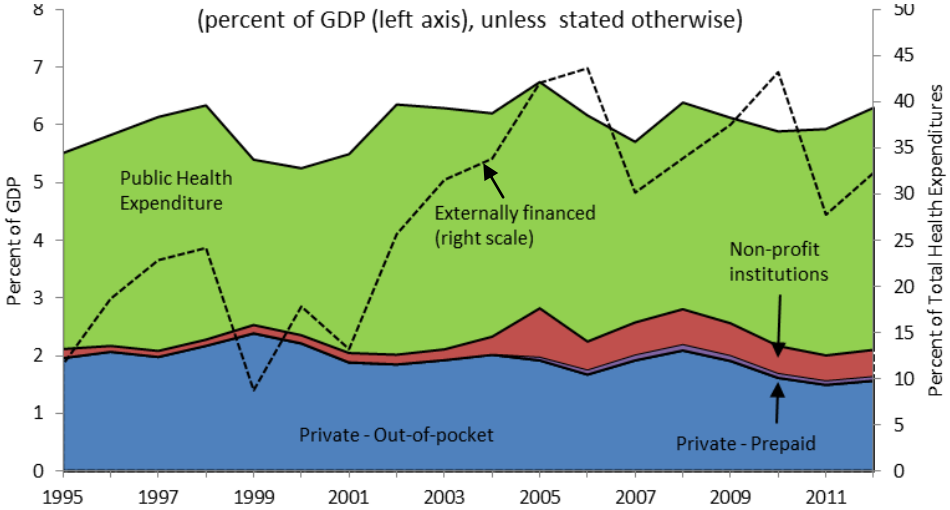
Source: OECD (2014).

Note: Excludes debt forgiveness of US$1.2 billion in 2005 and US$3.6 billion in 2006.

Health financing in Zambia

In 2012, according to the latest data from WHO and World Development Indicators, Zambia's total health expenditure was US$1.35 billion with US$96 per capita health expenditure. Of the total expenditure on health, 64% was Government domestic expenditure on health (US$ 868 million, which is equivalent to 4.2% of GDP). External funding for health was estimated at US$ 437 million in 2012, which accounts for 32.3% of total health expenditures in 2012. While external funding for health increased from US$13.3 million (or 17.8% of total health expenditure) in 2000, it fluctuated greatly during this period (**Figure 12**). The majority of external financing for health would have been for HIV.

Figure 12 Zambia: Health expenditure by source of financing (1995–2012)

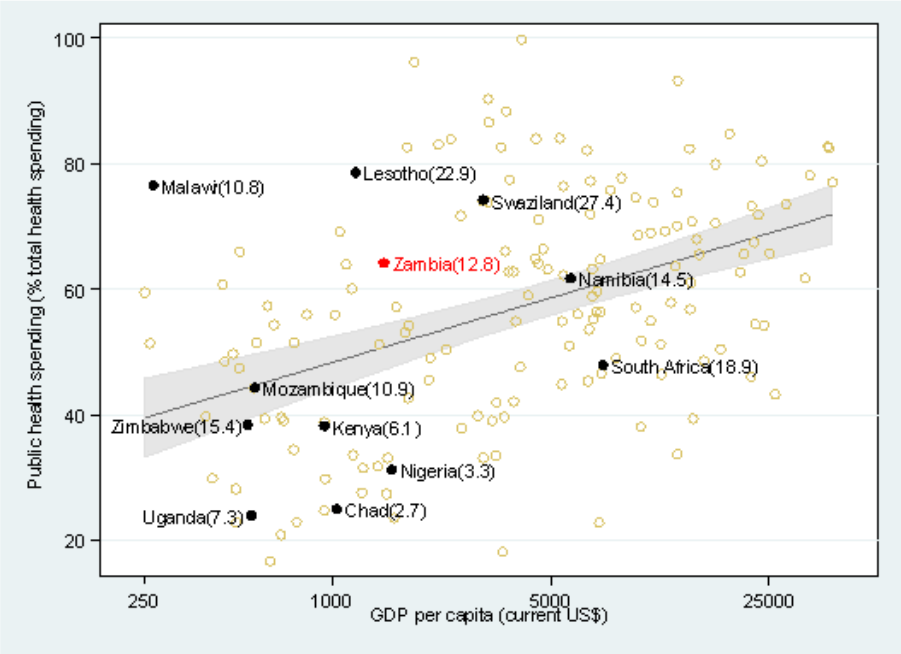


Source: WHO (2012)

Figures 13 and 14 relate Zambia's government expenditure on health and Zambia's domestic HIV financing contribution relative to other countries with similar GDP levels in the region. They show that: (a) **Zambia's government expenditure on health is relatively higher than in other**

countries; (b) **in 2012 domestic HIV spending as a share of total HIV expenditure was low at 6%.** Kenya, for example, who's GDP per capita is lower than Zambia's at US$ 994, contributed higher levels of domestic resources to the national HIV response: US$153.4 million or approximately 20.8% of total HIV spending in the country in 2013 (**Figure 13** and **Figure 14**).

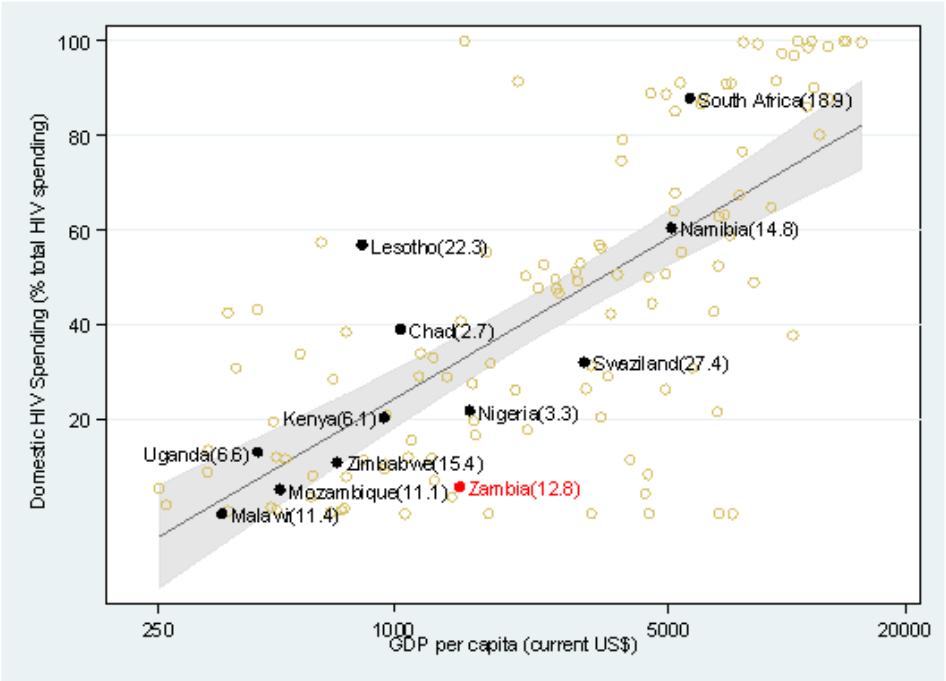
Figure 13 Public health expenditure as a share of total health expenditure



Source: World Development Indicators & WHO, 2014.

Note: X-axis log scale; High HIV prevalence (> 2.0%) countries; Public health expenditure shares are for most recent available year 2000–13; GDP per capita 2013; HIV prevalence in parentheses.

Figure 14 Domestics HIV Expenditure as a Share of Total HIV Expenditure



Source: World Development Indicators and WHO, 2014.

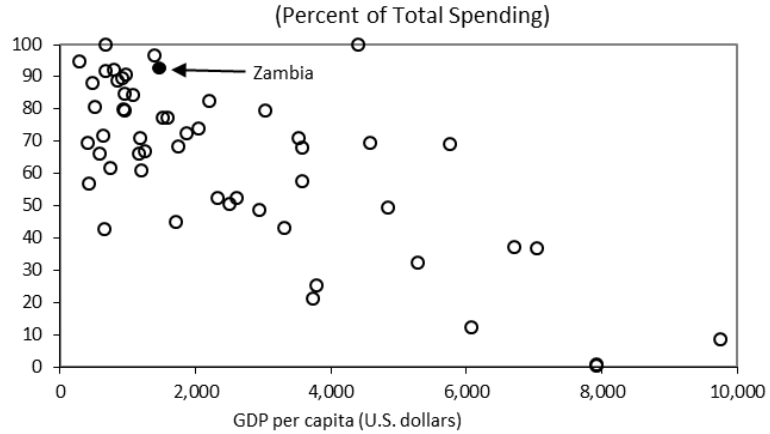
Note: X-axis log scale; High HIV prevalence (> 2.0%) countries; Domestic HIV expenditure shares for most recent available year 2000–13; GDP per capita 2013; HIV prevalence in parentheses.

HIV financing in Zambia

***Total HIV spending*:** According to the National AIDS Spending Assessment (NASA) 2010–12, total HIV spending for Zambia in 2012 was approximately US$283 million which increased from US$269 million in 2011. The costs of the national HIV response were equivalent to almost 7% of overall government expenditures in 2012.

***External financing for HIV*:** The bulk of HIV funding came from external sources, and the rest came from the government and private sources. **Figure 15** illustrates the high dependency of Zambia on external assistance using most recent data.

Figure 15. Externally financed HIV spending across countries (2012)



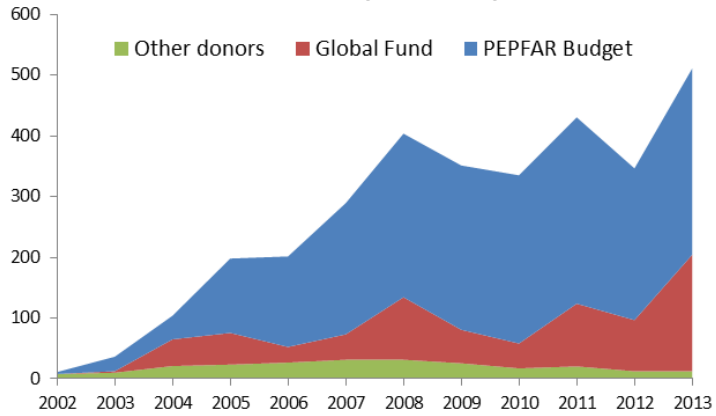
Source: Own calculations based on data from UNAIDS (2014) and IMF, WEO (2014).

External aid contributed US$264 million in 2012, which accounts for 93% of the total AIDS spending in that year. With rapidly increasing contributions from PEPFAR and Global Fund after 2004, the proportion of the national HIV response financed by external donors grew subsequently and was at 61% in 2007, 74% in 2008, 91% in 2009[4], 95% in 2010 and 92% in 2011.[5] Among the external sources, the US Government through the PEPFAR initiative is the major funder of the AIDS response followed by the Global Fund. In 2012 PEPFAR financed US$204.4 million (of the total budget of US$249.7 million) while the Global Fund disbursed US$84.2 million (**Figure 16**).

[4] Calculated from data from the Zambia Public Expenditure Tracking Survey (table 20).

[5] Data from the 2010-12 NASA.

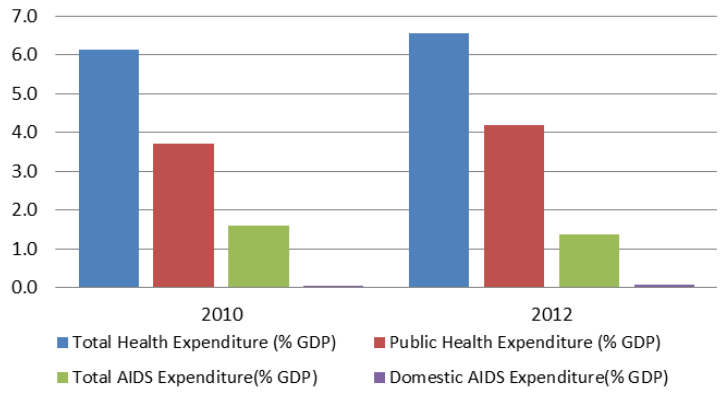
Figure 16 Zambia: HIV/AIDS-related aid disbursements, US$ millions (2002–13)



Source: OECD CRS (2014); PEPFAR budget analysis data (2014).

Domestic financing for HIV: The government of Zambia contributed to the HIV response US$15.8 million in 2012, which accounts for 6% of the total HIV expenditure and for only 1.8% of the public expenditure on health. Much of the public HIV spending comes from the central government. However, the NASA data does not fully account the indirect spending for HIV, which underestimates the overall government contribution to the HIV spending in the country. **Figure 17** summarises for two NASA years (2010 and 2012), the GDP shares of total and government-only health and HIV expenditures, again illustrating the point of very low domestic HIV spending in these assessment years.

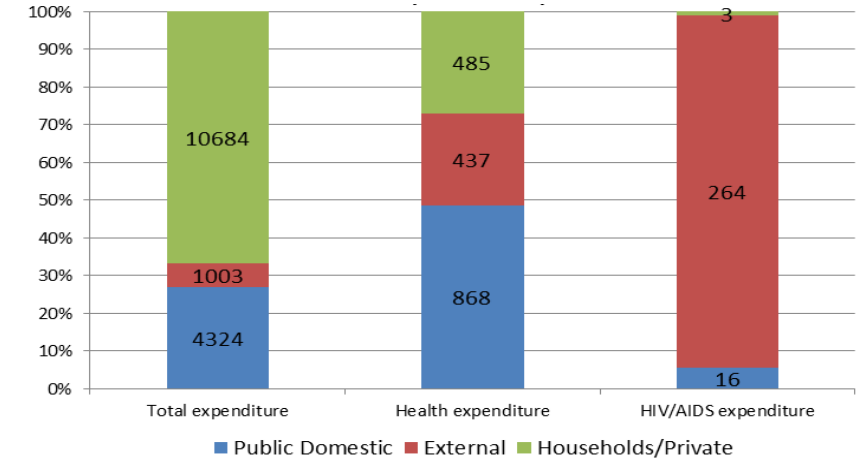
Figure 17 Health and HIV expenditures as a share of GDP, Zambia (2010, 2012)



Source: WHO and WDI (2014); NASA (2014).

Figure 18 shows the shares of household, public, and external aid contributions to the total expenditure as well as to health and HIV expenditures in 2012. The imbalance between what government spends on health as compared to HIV is clearly shown here. The data suggest that the population is largely protected from spending for HIV services (low household expenditure for HIV), but contributes significantly to total health expenditure.

Figure 18 Zambia's total, health and HIV/AIDS expenditures by sources, US$ millions (2012)

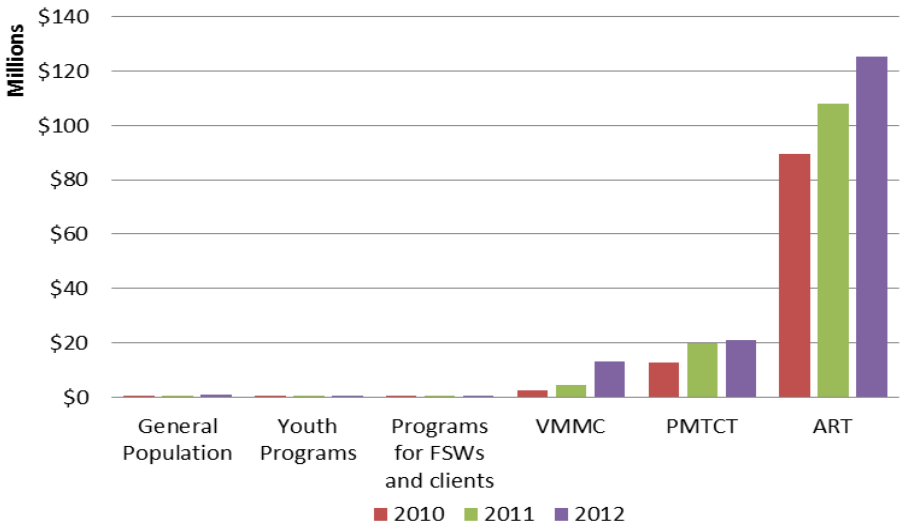


Sources: OECD, WHO-NHA; Zambia NASA 2012 and (world development indicators (WDI) databases.

2.3. What HIV Financing has accomplished in Zambia

Between 2010 and 2012, by far the majority of HIV funding has been spent on the ART, male circumcision and PMTCT programmes. Figure 19 shows expenditure by main HIV programme area over the last three years of NASA data. This figure shows that spending on ART significantly increased from US$23 million in 2005 to US$125 million in 2012, while other programmes remained relatively constant except for the voluntary medical male circumcision (VMMC) programme. Indirect costs and critical enablers consumed about 30% of total resources spent on Zambia's HIV response.

Figure 19 HIV expenditure by selected key programmes in Zambia (2010–12)

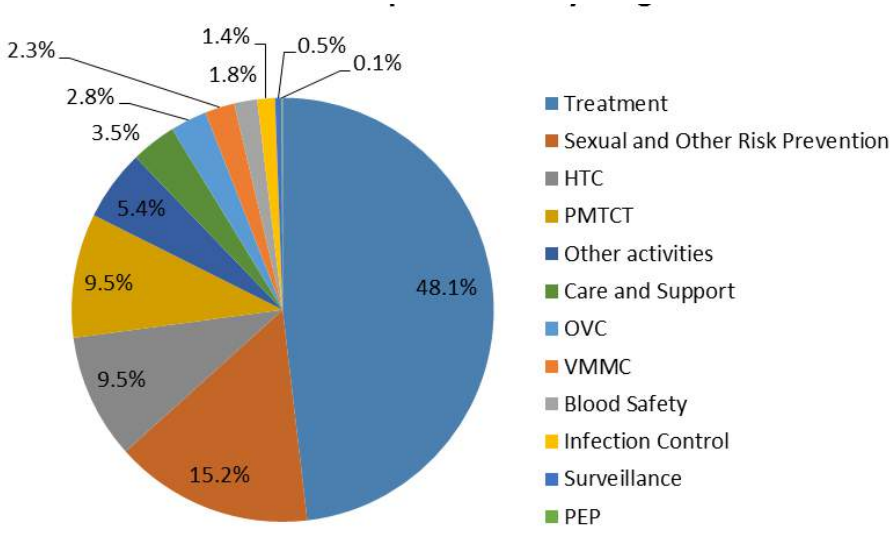


Source: NASA reports (2010–12)

The spending on ART, VMMC and prevention for key populations is largely funded by external sources. In 2012, PEPFAR spent about US$98 million (48% of their US$204 million

support) on ART and US$4.6 million on VMMC, which accounted for 96% of total spending on ART and 78% of total VMMC spending in Zambia (**Figure 20**).

Figure 20 PEPFAR expenditure by programme area, Zambia (2012)



Source: PEPFAR Funding Dashboard (2014) – http://www.pepfar.gov/funding/c63793.htm.

Notes: HTC = HIV testing and counselling, PMTCT = prevention of mother-to-child transmission, OVC = orphan and vulnerable children support, VMMC = voluntary medical male circumcision, PEP = post-exposure prophylaxis.

These data underline the challenges Zambia faces with financing its HIV response in the long-term. **Table 1** summarises key statistics on HIV spending in the last available NASA year 2012.

Table 1 Key statistics on HIV Spending, Zambia, 2012

Total HIV spending in 2012, US$	**282,563,078.00**
Shares of total HIV Spending	
International	93.3%
of which Global Fund	*4.9%*
of which PEPFAR	*91.1%*
Domestic public	5.6%
Private (for profit institutions, household funds and other private sources)	1.1%
Total HIV spending as share of GDP	**1.4%**
Total HIV spending per capita, US$	**20.08**
Total HIV spending per people who live with HIV, US$	**255.31**
Shares of total HIV Spending	
Prevention	16.7%
of which for "Vulnerable groups"	*0.5%*
of which PMTCT	*22.5%*
Care and treatment	36.4%
of which ART	*67.0%*
Orphans and vulnerable children	3.1%
System Strengthening and Programme Coordination	35.3%

Sources: NASA; IMF 2014 World Economic Outlook Database, April 2014 edition; UNPD, WPP 2012.

2.4. Progress with Implementing HIV Services in Zambia

Amidst various challenges, several key advancements have been reported across the priority HIV programmes defined in Zambia's HIV strategy (NASF 2011–15). Based on government reports and available data (including UNGASS progress report 2014, and draft Global Fund concept note), implementation progress can be summarised as follows:

2.4.1 Antiretroviral therapy

The ART programme has seen rapid expansion after ART became a national strategic priority and PEPFAR support started in 2004. By 2012, the number of health facilities dispensing ART (564) was already higher than the target of 500 set for 2015.

As of December 2013, the number of children and adults currently receiving ART in accordance with the nationally approved treatment protocol was 580,118 (81.9% coverage, UNGASS 2014 report). Of all individuals enrolled in ART, 530,702 were adults (Global Fund concept note).

In an effort to address human resource challenges, HIV nurse practitioners have been trained to initiate patients on ART for patients with non-complicated HIV or no other major infections. General nurses are only allowed to maintain patients on ART. Community Health Assistants (CHAs) can perform rapid HIV tests but are not licensed or allowed to re-supply patients with ARVs.

ART adherence and survival rates have improved recently—the percentage of adults and children with HIV known to be on treatment 12 months after initiating ART has increased to 80.6% in December 2013, as compared to 76.5% in 2011 and 65.1% in 2010.

The death rate from HIV/AIDS among adults has reduced by two-thirds in 10 years, from 1.02% in 2002 to 0.34% in 2011 (similarly, the death rate due to HIV/AIDS among infants reduced by over three-quarters from 1.51% in 1997 to 0.33% in 2011, largely due to the introduction of the PMTCT programme).

In future, with the introduction of ART initiation at higher CD4 counts for some sub-populations such as TB/HIV co-infected patients and discordant couples, the Zambian authorities expect further gains in lowering HIV transmission and incidence.

2.4.2 Voluntary medical male circumcision

By end 2013, Zambia had reached 33% of the target needed to circumcise 80% of men aged 15 to 49. [14] The VMMC scale-up, started in 2008 (2,758 VMMCs) has multiplied the annual number of procedures ever since, reaching 294,466 VMMCs in 2013 and a cumulative total 2008–13 of 635,458.

The scale-up of VMMC service is guided by the Country Operational Plan for the period 2012–15 which was developed in April 2012.

The number of sites providing VMMC services increased from 135 in 2010 to 287 at the end of 2011.

To support rapid scale up, Zambia has adopted a policy on task shifting (clinical officers and nurses allowed to conduct VMMCs). In addition, trained staff is allocated to general hospitals in selected provinces, as per VMMC demand. [15] Also, there are outreach services in addition to static services during VMMC campaign months.

Although there has been a rapid increase in the number of annual VMMC procedures, the figures have fallen somewhat short of annual targets—for instance, in 2012, a total of 173,992 out of a planned 200,000 procedures were done. Still, together with South Africa, Uganda, Kenya and Tanzania, Zambia has made the most strides in circumcising men (all above 600,000 procedures in 2008–13). In terms of progress towards the 80% coverage target, Zambia ranks in third place at 33%, after Kenya and Tanzania (which both had relatively high levels of pre-existing male circumcision).

2.4.3 Prevention of mother-to-child transmission

The scale-up of PMTCT is regarded as a key achievement in recent years and a global success story. It goes hand in hand with the further increased uptake of ANC services from 94% in 2007 to the near-universal level of 96% in 2013–14 (DHS data).

The estimated number of pregnant women in 2012 was 723,436. Of these, 688,060 (94%) attended ANC services at least once and were tested for HIV.

The number of women living with HIV who delivered in 2012 was 81,727 out of which 88% received efficacious ARVs for PMTCT up from 58% in 2009.

In 2013, this percentage increased further to 97%, with 75,165 women out of 77,772 receiving ARV drugs to reduce the risk of mother-to-child transmission (MTCT).

In 2013, 71.6% of infants born to HIV positive mothers received a virological test for HIV within 2 months of birth

These efforts have translated into a drop in the estimated HIV transmission rate from mother-to-child from 24% in 2009 to 12% in 2012—Zambia is on track to meet the target of reducing the number of new HIV infections among children by 90% by 2015.

2.4.4 HIV counselling and testing to identify unknown PLHIV

There was an increase in HCT uptake in the general population, though not at the desired rate (UNGASS report). By December 2013, the number of people who received HCT services in the past 12 months and obtained their test results aged 15 and older was 2,066,216 (HMIS, 2013). More women had used HCT services than men.

The number of health facilities offering HCT increased from 56 in 2001 to 1,800 in 2012.

There is an urgent need to understand what proportion of PLHIV knows about their HIV positive status.

2.4.5 Condoms and education on sexual HIV risk reduction

Condom distribution and promotion is guided by the Comprehensive Condom Programming Strategy and Operation Plan 2010–14. The goal of the strategy is to make quality condoms available, accessible and affordable to all sexually active individuals throughout Zambia by 2014.

The recent IHME/UNZA assessment of health facility performance [16] reported that among contraceptive methods, condoms were most widely available across platforms, probably due to their multiple use for family planning, HIV and STI prevention. With the exception of private hospitals, which generally had the lowest availability of most contraceptive options, at least 70% of all facilities across platforms offered condoms and at least one type of female family planning method. Notably, 96% of rural health centres had these two forms of modern contraceptives; this is an improvement from the 2005–06 PET/QSDS that found a substantial gap in self-reported capacity for and facility-based availability of family planning options among rural health centres. [17]

Low and inconsistent use of male and female condoms—despite increased availability of both male and female condoms—remains a challenge.

Significant efforts have been made to empower women to take control of their sexual and reproductive health, however, there is evidence that women are still less likely to negotiate and/or demand the use of condoms with partners (there has however been very significant progress in the use of modern family planning methods which was among married women at 15% in 1992, 26% in 1996, 34% in 2001–02, 41% in 2007 and 49% in 2013–14—DHS data).

The target for 2011 to 2015 is to increase the percentage of females and males aged 15–49 who had more than one partner in the past 12 months and used a condom during their last sexual intercourse from 37% for females and 50% for males in 2007 to 55% for females and 70% for males by 2015.

Knowledge of HIV and AIDS is high among young people aged 15–24 years—more than 90% of them have heard about HIV. However, comprehensive knowledge about HIV and AIDS remains low. Only 36% of women and 39% of men have comprehensive knowledge.

Curable sexually transmitted infections continue to represent a large burden of disease in Zambia, accounting for about 10% of out-patient visits. For, example, the RPR positive rate in the 15–49 age-group was 7% for women and 8% for men (2001–02 ZDHS), while prevalence levels of gonorrhoea, chlamydia, trichomoniasis and syphilis among FSWs were 10.4%, 6.8%, 38.8% and 23.3%, respectively, in the surveys of the Corridors of Hope project (2006).

2.4.6 HIV services for key populations at higher risk

According to the 2014 UNGASS report, access of FSW and MSM to HIV prevention services is not known.[6]

Similarly, there is no recent data on condom use with clients or partners, uptake of HCT, or proportion of FSW/MSM living with HIV. According to the 2014 UNGASS report, 97% of FSW reported ever having used a condom (2009 data), and an increasing proportion have condoms "at hand" (24% in 2000, 60% in 2009).

Activities relating to sex work, sex among same sex couples, and drug use are illegal in Zambia. Laws that outlaw same-sex behaviour, drug use and sex work have been shown to increase vulnerability to HIV and create barriers to accessing services, while also undermining basic human rights.

In both FSW and MSM, it is thought that vulnerability and risk factors such as alcohol abuse, gender based violence, stigma and discrimination, low levels of educational attainment and overall levels of poverty, may further compound their risk of HIV exposure. Children are a particularly vulnerable group as 9% of 10–19 year olds had reported having traded sex for food or money.

In the UNGASS National Composite Policy Index (NCPI) rating, the score for human rights has continued its downward trend decreasing from a score of 7 in 2007 to a score of 1 in 2013.

2.4.7 Services to mitigate the impact of HIV/AIDS

The interventions under the impact mitigation programme area have focused on strengthening the capacity of vulnerable households and individuals to cope with the socio-economic impacts of HIV and AIDS.

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[6] Note that in Zambia, key populations have been defined as "People living with HIV, women and children, adolescents (10-14), young people (15-24), people with disabilities, prisoners, sex workers and their clients, migrant and mobile populations (The NAC Council 8th February 2014)

PLHIV, orphans and vulnerable children (OVC), people with disabilities, and care-givers were recognised as the key vulnerable groups. The multisectoral approach of the NASF programmes, through formation of District AIDS Task Force (DATF) in districts countrywide has provided successful achievements in mobilising a substantial number of civil society organisations to respond to the needs of OVCs and vulnerable households by providing health related and other services.

Key milestones attained in the coordination and management of the national response (the fourth priority area of the NASF after prevention, care and treatment, and impact mitigation) include enhanced visibility, ownership and leadership of Government and the National AIDS Council in particular on coordinating the multisectoral national HIV and AIDS response. Weaknesses include governance challenges and a lack of integration with health service delivery.

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CHAPTER 3. MODELLING ANALYSIS OBJECTIVES AND PARAMETERS

3.1. Objectives of Optimisation Analysis

Allocative efficiency occurs when the right mix across HIV programmes leads to desired outcomes. To allocate HIV programme investments efficiently requires an understanding of future epidemiological trends and the impact of various programmes on epidemiological outcomes. Based on the main objectives of the R-NASF 2014–16, the following two analyses were conducted:

a. An assessment of the allocative efficiency of spending on HIV programmes in Zambia in terms of HIV incidence and AIDS related deaths over 2013–30. The specific question was what resource allocation to the different HIV programmes (relative to the current allocation) minimises the cumulative HIV incidence and cumulative HIV related deaths over 2014–30.

b. An estimation for the minimal spending required to achieve key outcomes in the R-NASF over 2013–30. As for most governments, the Government of Zambia desires to achieve multiple objectives whilst simultaneously minimising the amount of investment required. The review of the Zambia National AIDS Strategic Framework for 2011–15 lists the following impacts and outcomes as objectives:

Impact 1: Avert between 170,000 and 360,000 new HIV infections by 2030

Impact 2: Avert between 60,000 and 123,000 AIDS-related deaths by 2030

Outcome 1: The rate of annual new HIV infections reduces from 53,000 in 2012 to 38,662 in 2016

Outcome 2: The percentage of infants born HIV positive reduces to less than 5% by 2016

Outcome 3: The percentage of PLHIV alive 36 months after initiation of antiretroviral therapy has increased from 81% in 2013 to 85% by 2016

We carried out an optimisation analysis that at the same time optimises for reductions in HIV incidence and AIDS deaths. Based on strategic objectives in the NASF 2011–15, we calculated that **these impacts correspond to a 21–45% reduction in cumulative new infections, a 14–29% reduction in AIDS deaths, and a 7–40% reduction in child infections over 2014–30.** This corresponds to a reduction in new infections of approximately 1.5 times greater than for AIDS

deaths. Based on this ratio, in our optimisation analyses we weighted preventing new infections (including MTCTs) 1.5 times more than preventing AIDS deaths.

To determine the minimal spending required for achieving these impacts we considered two optimisation scenarios:

a. Moderate optimisation scenario

   Compared to current expected trends over 2014–30, determine the minimal spending required to:

   - Reduce new infections by at least 21%
   - Reduce HIV related deaths by at least 14%
   - Reduce new mother-to-child transmissions by 7%

b. Ambitious optimisation scenario

   Compared to current expected trends over 2014–30, determine the minimal spending required to:

   - Reduce new infections by at least 45%
   - Reduce HIV related deaths by at least 29%
   - Reduce new mother-to-child transmissions by 40%

3.2. Optimisation Analysis Framework

Table 2 Modelling framework

Category	Parameterisation in Optima
Populations defined in model* * Other populations excluded due to a lack of data: People who inject drugs (PWID), Prisoners	▪ Female children aged 0–9 years ▪ Male children aged 0–9 years ▪ Females aged 10–19 years ▪ Males aged 10–19 years ▪ Females aged 20–24 years ▪ Males aged 20–24 years ▪ Females aged 25–29 years ▪ Males aged 25–49 years ▪ Females aged 50+ years ▪ Males aged 50+ years ▪ Female sex workers (FSW) ▪ Men who have sex with men (MSM)

Category	Parameterisation in Optima
	For the purposes of programme spending allocation, we label males and females aged 10–24 as youths and males and females older than 25 as adults
Expenditure areas defined in model and included in optimisation analysis	▪ Targeted prevention services for youths (including condoms and BCC but excluding ART) ▪ Targeted prevention services for adults (including condoms and BCC but excluding ART) ▪ Targeted prevention services for FSW and clients (including condoms and BCC but excluding ART) ▪ Targeted prevention services for MSM (including condoms and BCC but excluding ART) ▪ Voluntary medical male circumcision (VMMC) for males younger than 50 years of age (excluding MSM) ▪ Prevention of mother-to-child transmission (PMTCT) ▪ HIV counselling and testing (HCT; for all population groups excluding children)—only diagnosed people can begin ART so HCT enables early initiation of treatment and can enable a larger proportion of PLHIV to be on treatment. ▪ ART (including first and higher line drugs for adults and paediatric ART for children; excluding care and support for people living with HIV)
Expenditure areas not included in optimisation (effect on HIV incidence, morbidity/mortality not understood)	▪ Care and support for people living with HIV ▪ Programme management and administration ▪ Human resources ▪ Social protection and social services ▪ Enabling environment ▪ Research ▪ Post-exposure prophylaxis (PEP), orphans and vulnerable children (OVC), and blood safety were treated as fixed essential costs
Time frames	▪ 2014–16 (end year of current R-NASF) ▪ 2014–30 (current timeframe for review of R-NASF)
Assumed coverage/spend in the forward projection to 2030	▪ VMMC 80% maximum coverage of all susceptible males aged below 50 years ▪ PMTCT maximum coverage of all HIV+ pregnant women 98%

Category	Parameterisation in Optima
	▪ ART coverage of diagnosed PLHIV with CD4 < 500 cells/ml can reach 100% ▪ ART spending is maintained to ensure the maximum number of people who have initiated ART are being provided with continuous ART services
Baseline scenario /counterfactual HIV epidemic projection	The baseline scenario is an epidemic projection produced by Optima assuming constant spending of 2013 expenditure allocated as per the estimated 2013 distribution The epidemic and financial impact of this scenario is used as a counterfactual against which the extent of reductions in new infections and deaths as well as savings with optimal allocations are measured
Baseline scenario funding (ART and VMMC spending based on unit cost estimates while other programme costs are based on 2012 NASA)	Estimated spending in 2013, US$ 413 million (all spending) Estimated US$ 242 million (programmatic spending optimised in our analysis) including ▪ US$ 148.6 million (ART spending based on an average unit cost of US$ 280) ▪ US$ 25.4 million (VMMC spending based on a unit cost of US$ 86.25) All other programmatic spending estimated from 2012 NASA using a 7% annual inflation rate

3.3. HIV Financial Commitment Analysis Framework

In addition to the optimisation exercises focusing on attaining objectives (like minimising AIDS deaths or HIV infections, conditional on some budget constraint) over some period, this report also offers a more forward-looking analysis that considers the costs caused by new HIV infections over the lifetime of PLHIV and long-term financial commitments of HIV policies that the Government has agreed to ('HIV financial commitment analyses').

This is useful because many people living with HIV in Zambia today already receive or are going to receive treatment, in line with the Government's national HIV strategy. Due to this commitment to provide HIV treatment made by the Government, HIV infections result in long-term government financial commitments that can extend over decades. Conversely, each HIV infection averted results in savings which are also spread over a long period. Understanding the consequences of alternative HIV strategies in terms of the long-term financial commitments is useful for assessing the cost-effectiveness of HIV investments and the consequences of these investments for the long-term financial sustainability of the HIV response.

The overall analysis is based on a microeconomic component (based on the costs of one HIV infection) and a macroeconomic component (focusing on the spending commitments under the national HIV response). The costs caused by one HIV infection are calculated by tracking one additional person who becomes infected over time. The costs caused by one HIV infection are obtained based on the objectives of the national HIV response (which determine the expectations regarding the transition to treatment), the unit costs of relevant HIV services, and the model describing the progression of the disease (with or without treatment).

The long term financial commitments are estimated using (a) the costs of the national HIV response in 2014, and, (b) the projected lifetime costs of the HIV response for all people living with HIV in 2014, which is discounted at a specified rate.

The point of this forward-looking estimation of long-term financial commitments is to estimate (a) the savings caused by HIV prevention interventions and include them in the analysis of the cost-effectiveness of these interventions; (b) the total long-term financial commitments caused by HIV infections; and (c) how these long-term commitments are changed by different strategy choices. In this analysis framework, an intervention that averts (at some unit cost) new HIV infections in 2014, would result in reduced long term HIV-related financial commitments. These long-term savings could, for example, refinance some of the initial programme costs and could even result in the initial programme turning out to be cost-saving to the Government.

Similarly, the long-term HIV-related financial commitments over some period, e.g., until 2030, include the projected spending over this period, in addition to the lifetime costs of services to all people living with HIV at the end of this period. From this perspective, for the same costs over the 2014–30 period, an HIV/AIDS strategy that averts more new HIV infections over this period is cheaper in the long-run because it commits less of the government's future resource envelope.

3.4. Limitation of Analysis

3.4.1 Limitations specific to Zambia

Epidemiological data is limited and scarce for recent years (HIV prevalence and incidence data from the 2013–14 DHS were not yet available). There was no reported HIV prevalence data for FSW and MSM since 2005 and the latest estimates for the general population were from 2007. This means our estimates and projections up and beyond 2013 are hard to validate. However, we calibrated the model to also align with Spectrum-predicted trends.

There is very limited data on the number of partnerships and the number of acts per partnership in Zambia. Based on this lack of data, we used the parameters describing sexual

partnerships numbers and acts within Optima for calibrating the model to match the epidemiological indicators for Zambia.

There is a concern of a growing HIV epidemic amongst people who inject drugs (PWID), particularly in Lusaka. It was the intention of this analysis to include HIV transmission through shared injecting equipment. However, there was insufficient data to include this population at this stage. Injecting drug use is probably happening in Zambia on a small scale, but there are no data on the size of the drug user population, the frequency of drug injection or sharing of injecting equipment (2007 MOT report and 2012 UNGASS report).

The analysis team did not have programmatic data on the non-treatment prongs of the PMTCT programme - HIV prevention among women of reproductive age and prevention of unwanted pregnancies among women living with HIV. The impact ascribed to PMTCT in the modelling analysis was therefore limited to prong 3 on prevention of MTCT.

3.4.2 Limitations of the modelling methodology itself

A limitation of our approach is the assumption that all changes in behaviour are assumed to be due to changes in programme funding. This assumption is common in epidemic models.

Another key limitation is the assumption that programme spending remains fixed after 2014 at the specified allocation. This is particularly important for VMMC where a large scale-up is planned followed by a withdrawal of funding as coverage reaches high levels and the need to circumcise large numbers of men is reduced. Fixing spending on VMMC means circumcision coverage will increase steadily over the analysis period. The then inability of the model to perform time varying spending analyses likely downplays the long term cost-effectiveness of VMMC (the revised version of the Optima model now allows time-varying expenditure).

For simplification, and due to a lack of local data on the relationship between these expenditures and the impacts of interest, spend for post-exposure prophylaxis (PEP), orphans and vulnerable children (OVC), and blood safety were treated as fixed essential costs.

The analysis uses past ratios of expenditure to coverage as a basis for determining programme cost (Kerr et al. submitted [18]). This approach of using past cost and results has a number of advantages over using projected costs from plans and budgets, which are ultimately predictions of future cost, but also has a disadvantage, as there may be future increases or decreases in cost in relation to new approaches, implementation arrangements or technologies.

The modelling approach used to calculate relative cost-effectiveness between programmes includes assumptions around the impact of increases or decreases in funding for

programmes. These assumptions are based on unit costs and observed ecological relationships between outcomes of programme coverage or risk behaviour and the amount of money spent on programmes in the past, and assuming that there would be some saturation in the possible effect of programmes with increases in spending.

The analysis did not determine the technical efficiency of programmes as this was beyond the scope of the analysis, however, gains in technical efficiency would lead to different unit costs and therefore affect optimal resource allocation. Effects outside the HIV endpoints are not considered (e.g. wider effects of PMTCT within MCH, of condom use as a contraceptive, or effects of sex work interventions on STIs and SRH). Equally, the analysis did not include any synergies with, or relevant investments of, other development sectors, which may affect upstream social and structural co-factors of the epidemic (such as school enrolment).

Our approach does not consider equity or quantification of human rights, stigma and discrimination, ethical, legal or psychosocial implications.

Other models may produce different epidemiological projections than those produced by Optima. However, our model used the best available data and produced realistic forecasts, which was also well aligned with the projected trends by Spectrum.

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CHAPTER 4. MODELLING METHODS

4.1. Overview of Optima

Optima is a population-based HIV transmission and infection progression model. It can assess HIV epidemic trends, resource needs, the cost-effectiveness of past programmes, and the impact of potential future programmes using a detailed mathematical model of HIV transmission and disease progression. We provide a brief summary of Optima with technical details in **Appendix 1**.

Optima is a flexible model that can perform detailed country-specific HIV programme evaluations. It can build on the results from Goals to assess allocative efficiency and the resources required to achieve complex objectives over varying periods. Optima includes a model of HIV transmission and progression to track the movement of people between health states and population groups. The model incorporates the effects of different sexual partnership types, condom use, the sharing of needles and syringes, infection stage, CD4 count categories, homosexual and heterosexual partnerships, the extent of male circumcision, diagnosis, first and second line ART, and treatment failure on the transmission of HIV and infection progression.

Optima requires detailed demographic, epidemiological, behavioural, clinical, and health economic data which is entered using an Excel spreadsheet. Data entry is flexible, allowing everything from a separate data point for every population for each year, or a single data point for all populations over the entire simulation period.

Given available coverage, spending and outcome data for implemented HIV prevention and treatment programmes, Optima can determine the optimal allocation of resources or the amount of spending required to meet specified objectives (e.g., minimising infections, minimising AIDS deaths) or a combination of objectives. The model also enables additional programmatic scenarios representing the potential introduction of new programmes or changes to current programme implementation as required. Since this Optima analysis in Zambia, a Graphic User Interface has been developed for Optima in order to facilitate the use of this model by non-programmers.

4.2. Calibration of Optima to Zambia HIV Epidemic Data

For the period 2000–13, using all available demographic, epidemiological, behavioural, and clinical data (recorded in the Zambia.xlsx spreadsheet), we calibrated the Optima model predictions of HIV prevalence and incidence trends to actual Zambia HIV epidemic data

(**Figures 21 and 22**). During the calibration process, we also calibrated the model to align with the epidemic trends in prevalence, overall incidence, mother-to-child infections, and AIDS deaths obtained from Spectrum (see Appendix). Generally, Optima closely matches the available HIV prevalence and treatment data (we were unable to reconcile the lower prevalence in 10–19 year old males reported in 2001 with the prevalence trends in 10–19 year old females). Based on our calibration we estimated the overall and population level incidence over 2000–20.

Figure 21 Calibration of Optima to the HIV epidemic in Zambia

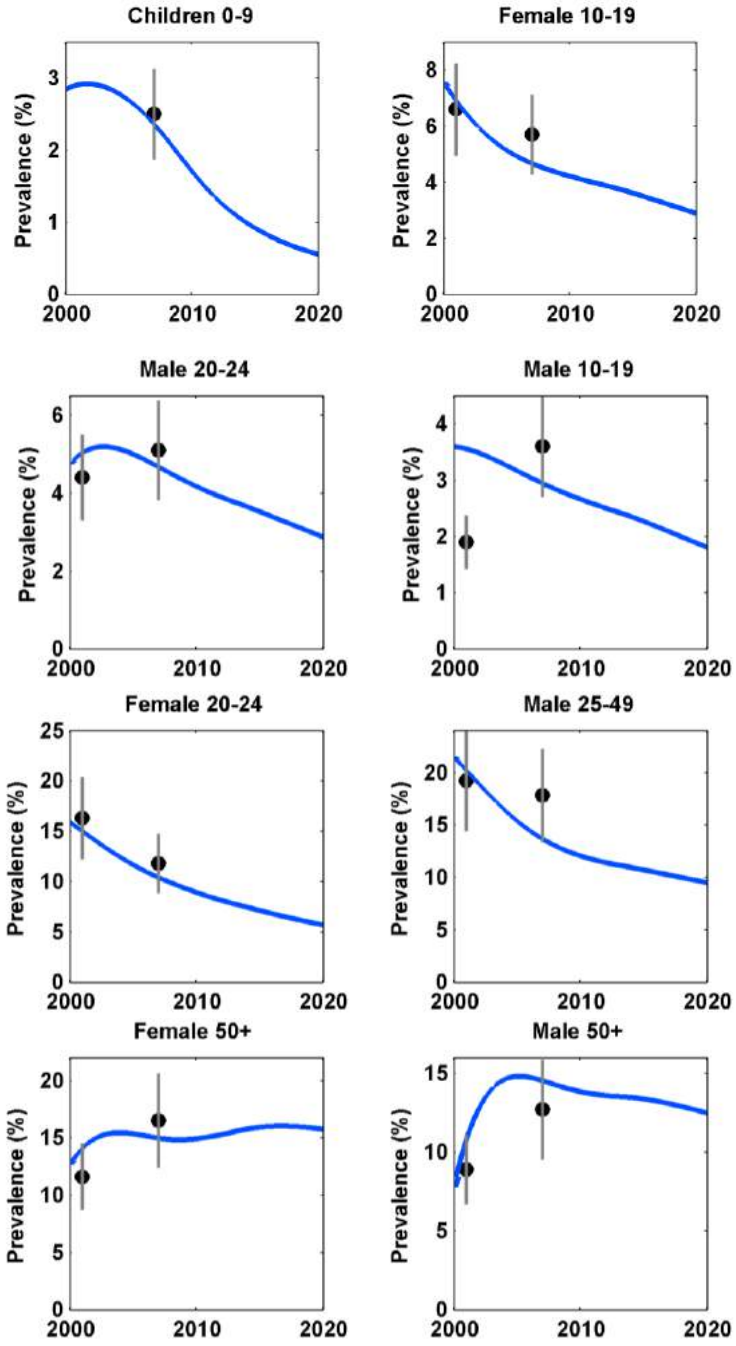

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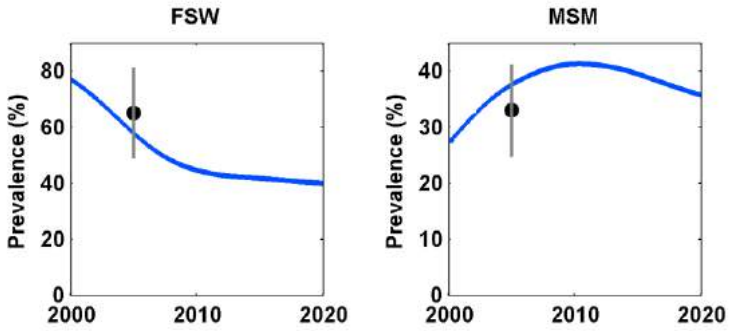
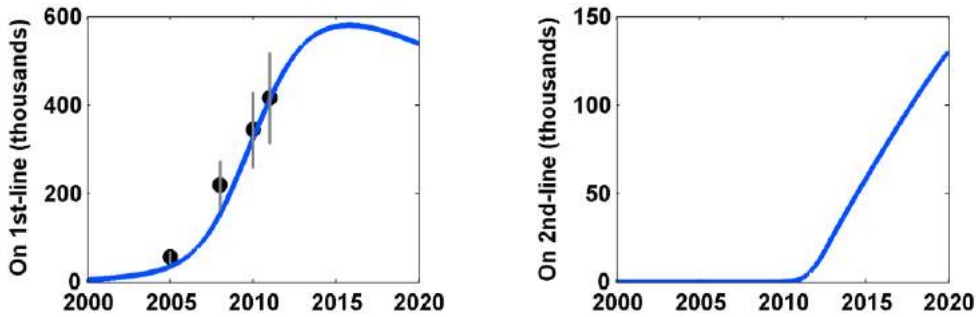
Figure 21 Calibration of Optima to the HIV epidemic in Zambia (continued)



Note: Black dots represent available data for HIV prevalence. Lines attached to these discs represent uncertainty bounds. The solid curve is the best fitting simulation used to produce the main findings.

Figure 22 Calibration of model to ART scale-up data in Zambia



Note: Black dots represent available data for the number of people on first and second line anti-retroviral treatment. Lines attached to these discs represent uncertainty bounds. The solid curve is the best fitting simulation and the light band represents the 95% confidence interval for the model outputs.

Calibration of Optima to Spectrum estimates: Over and above this calibration of Optima to actual epidemic data, we also calibrated the Optima epidemiological model estimates to align with the estimated epidemic trends in HIV prevalence, HIV incidence, mother-to-child infections, and AIDS deaths obtained from Spectrum (see Annex). For the 20 year and older age groups, epidemiological projections from Optima closely matches the available HIV prevalence and treatment estimates from Spectrum.

4.3. Estimation of Cost-outcome Relationships

The relationships between programme spending, and programme outcomes, developed in order to conduct resource optimisation analysis, are presented in **Figure 23** for different programmes and target populations in the form of logistic curves (thus not assuming linear scale-up or relationships).

Figure 23 Estimated cost-outcome relationships in Zambia

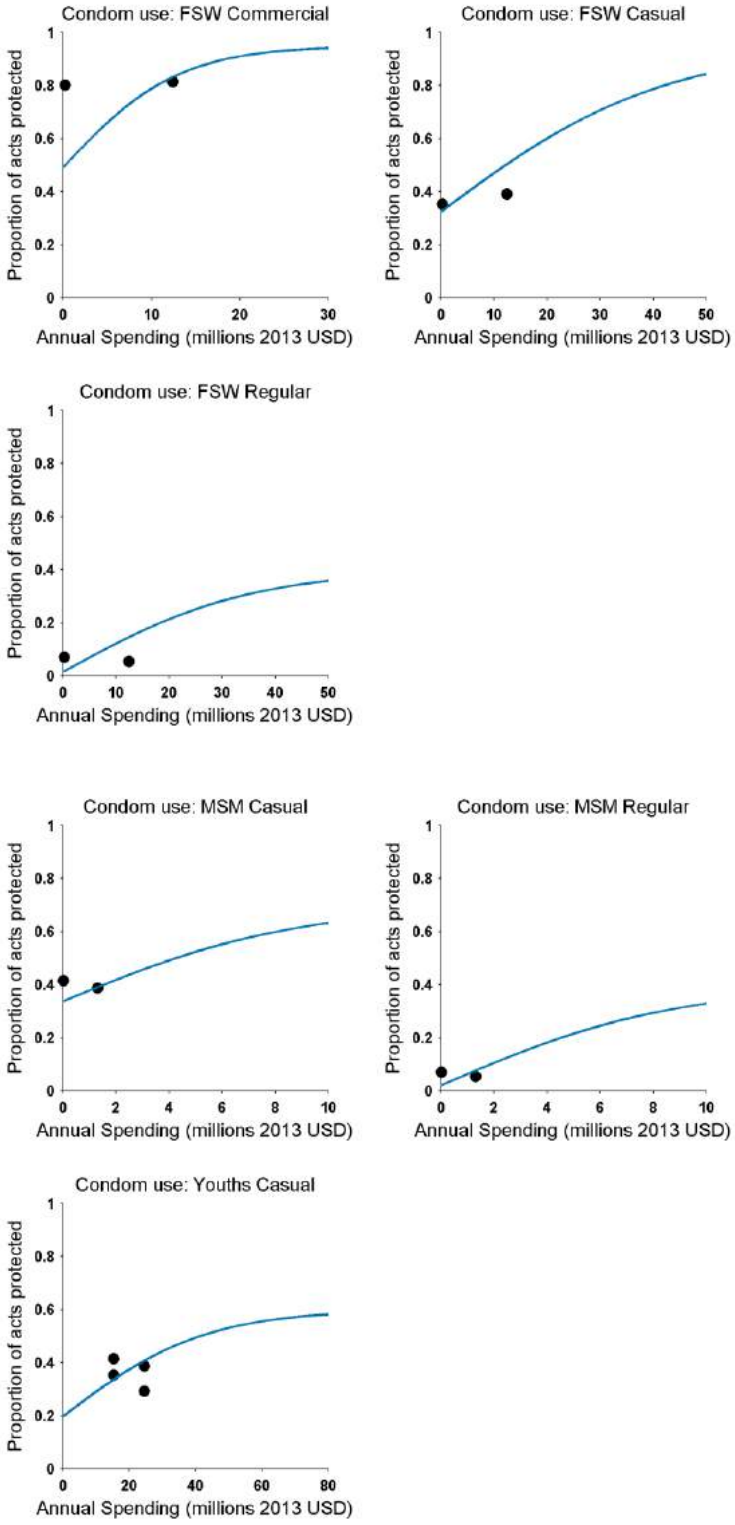


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Figure 23 Estimated cost-outcome relationships in Zambia (continued)

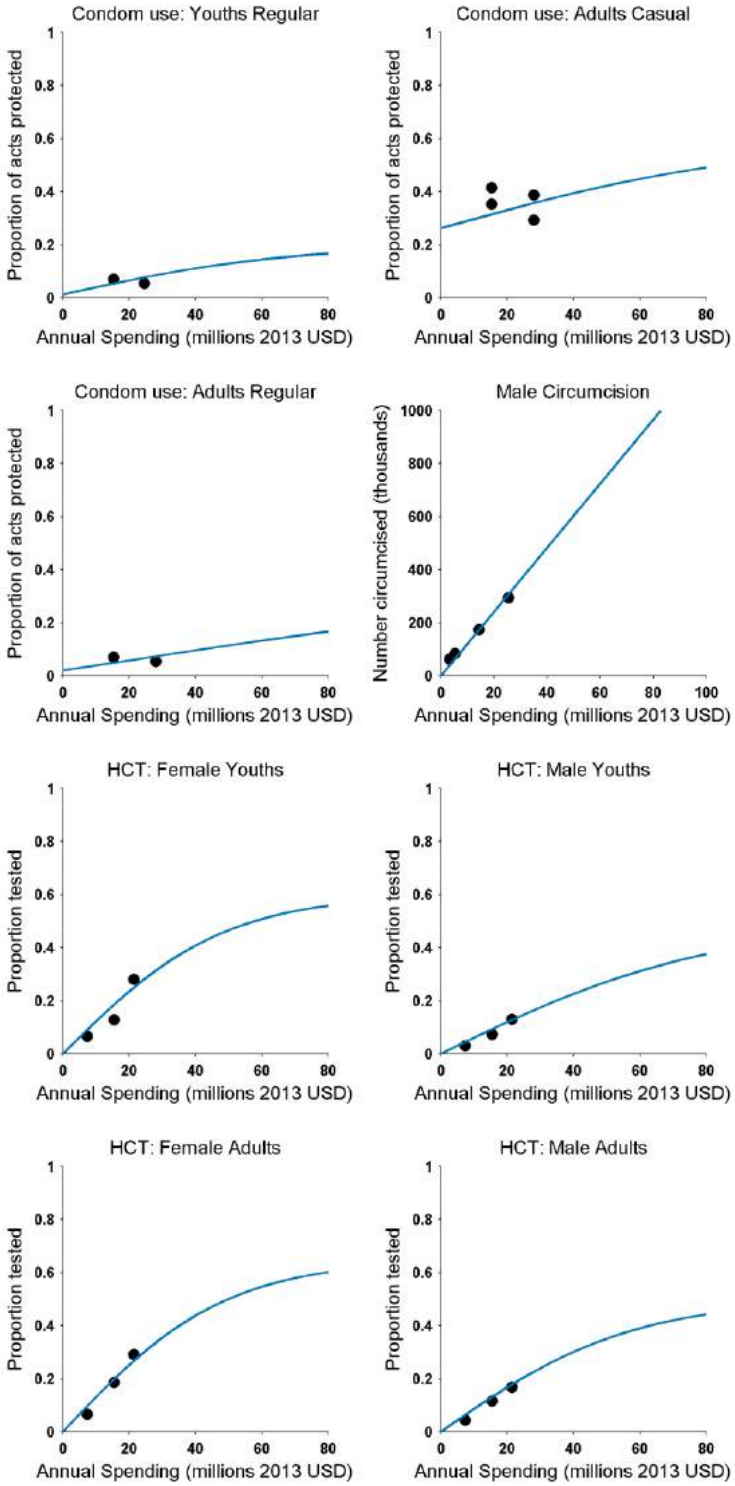

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Figure 23 Estimated cost-outcome relationships in Zambia (continued)

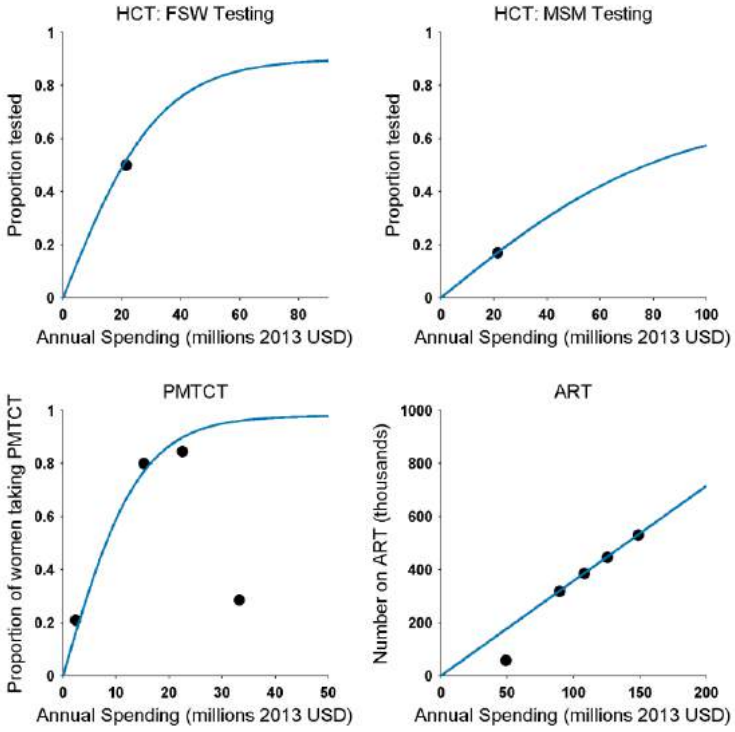


Table 3 summarises the process of arriving at average unit costs for each HIV programme.

Table 3 Unit costs established in the analysis (US$)

Programme	Unit costs, US$	Comment	Reference
VMMC	$86.25	Weighted average unit cost per male circumcision (excluding overhead costs)	Provided by CHAI from Spectrum RNM calculations from 2013 Spectrum workshop and 2014 R-NASF
First line ART for adults	$280 per person-year	Assumed average unit cost used for the optimisation analysis and represents the average cost of providing ART to a person each year. This value is also used for first line ART in the fiscal liability calculations	From 2013 Spectrum workshop based on CHAI "Multi-country analysis of treatment costs for HIV"
Second and higher line ART for Adults	$580 per person-year	Assumed unit cost for fiscal liability calculations for adult second line ART	Country-specific data on the costs of second-line treatment were unavailable at the time. Applied mark-up of US$300 to costs of first-line to account for higher drug prices

Programme	Unit costs, US$	Comment	Reference
Paediatric ART for children under 15 years	$368 per person-year	Assumed unit cost for fiscal liability calculations for first line ART for children used in fiscal liability calculations. Second line ART for children is assumed to have the same unit costs as adults	Based on the unit cost of providing ABC/3TC/LPV-r (1st line) in 2014 CHAI Spectrum RNM calculations for 2014 NASF
Non-treatment healthcare costs for PLHIV	$35 per person-year	Assumed unit cost for fiscal liability calculations providing non-treatment care and support to diagnosed PLHIV	Estimated from 2012 NASA by dividing the total spending allocated to care and support divided by the estimated number of people of PLHIV in 2012 (from Spectrum estimates)

Sources: National facility-based antiretroviral treatment costing study in Zambia, Zambia Ministry of Health/CHAI, 20 September 2012. This study reported ARV drug costs as follows (all per person per year): Adult first line - $152, adult second line - $550, paediatric first line $101, paediatric second line - $500, average across all categories - $155.

To conduct our analysis, we required an estimate for the level of spending on HIV programmes in 2013. We estimated spending on ART and VMMC programmes using available unit cost estimates and estimated population sizes (**Table 4**). For other HIV programmes, we assumed an increase from 2012 spending amounts using an annual inflation rate of 7% (based on CPI data for Zambia in the World Bank data bank). To convert 2012 spending in Zambian Kwacha to US Dollars we used an exchange rate of 5.15 Kwacha for 1 US$.

Table 4 Estimated programme spending in Zambia (2013)

	Estimated 2013 spending	Justification
General population programmes	$13,623,612	7% inflation from NASA 2012 spending
Youth programmes	$13,994,557	7% inflation from NASA 2012 spending
Programmes for FSWs and their clients	$340,492	7% inflation from NASA 2012 spending
Voluntary medical male circumcision programme	$ 25,397,693	In 2013 there were an estimated 294,466 voluntary medical male circumcision procedures carried out at a unit cost of US$86.25
MSM programmes	$30,011	7% inflation from NASA 2012 spending

	Estimated 2013 spending	Justification
PMTCT programme	$22,316,604	7% inflation from NASA 2012 spending
HIV counselling and testing	$17,919,322	7% inflation from NASA 2012 spending
ART programme	$149,000,000	In 2013 there were an estimated 530,702 people on ART with an annual treatment unit cost of US$280 (for first line therapy)
All other services and programmes	$170,930,478	7% inflation from NASA 2012 spending
Total	**$413,149,328**	

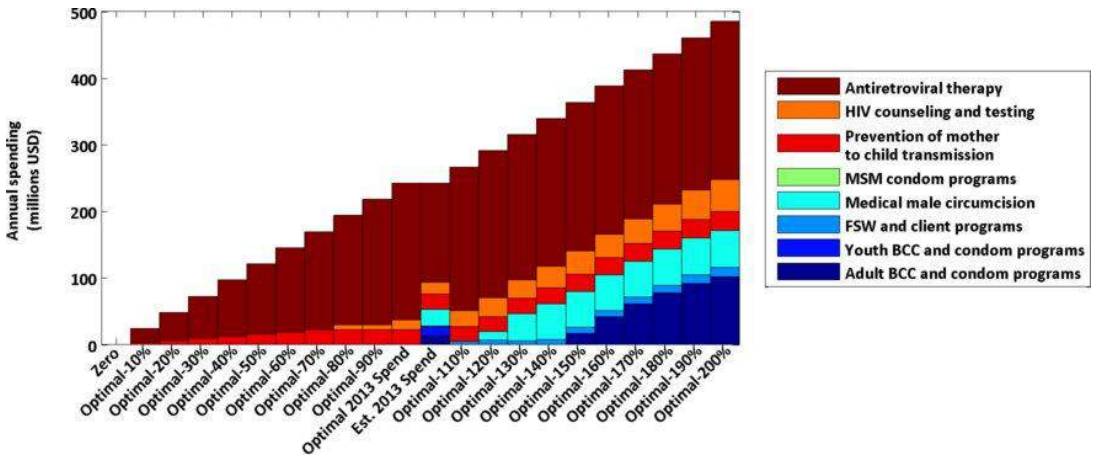
CHAPTER 5. MODEL RESULTS: OPTIMISING HIV RESOURCE ALLOCATIONS IN ZAMBIA

5.1. Optimised Allocations to Minimise Both HIV Incidence and AIDS Deaths at Different Funding Allocations

The optimisation analysis was carried out assuming different available funding levels, and the results are depicted in **Figures 24 and 25.** These figures show how the optimal allocation of resources to specific programmes, and the resulting impact, differ at different funding levels.

By allocating funds to more effective HIV programmes, it is possible to reduce the HIV epidemic and its mortality impact in Zambia. If the annual HIV budget available was the same as the estimated 2013 amount, remained constant over the 2014–30 period, and was optimised for HIV incidence and AIDS death reduction, HIV programmes could prevent 51,500 more HIV infections and 202,000 more AIDS deaths over that time period (**Figures 24 and 25**, comparing columns "estimated 2013 spend" and "optimal 2013 spend"). This would correspond to a 4.5% and 36%[7] further reduction in cumulative new infections and AIDS deaths, respectively, compared to current spending allocations.

Figure 24 Comparison of current and optimal HIV resource allocation for different levels of HIV resource availability to reduce cumulative new infections and HIV/AIDS related deaths, Zambia (2014–30)



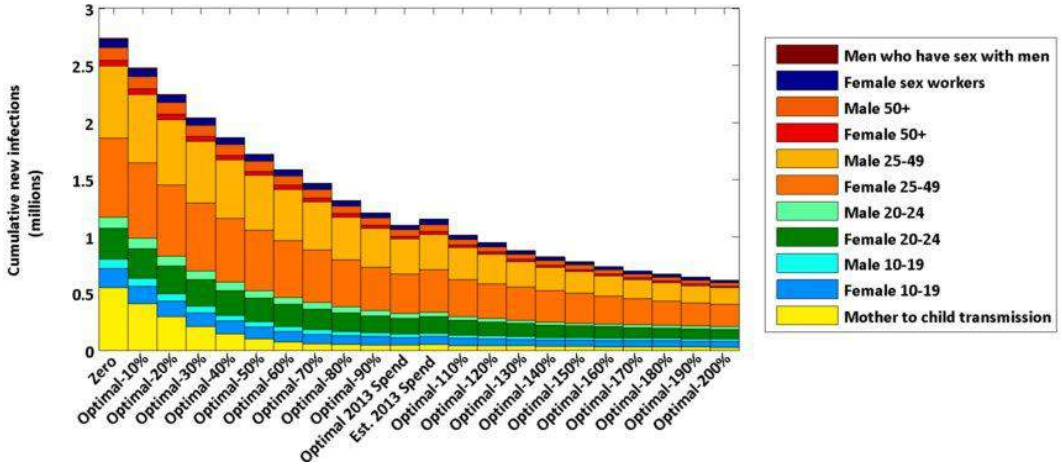
Source: Optima model Zambia, using available epidemic and response data
Note: This figure excludes indirect, management, and other non-optimised costs

[7] Note that this appears to be better than the minimal spending scenario below but is due to a different baseline. The minimal spending objectives are relative to current/projected trends.

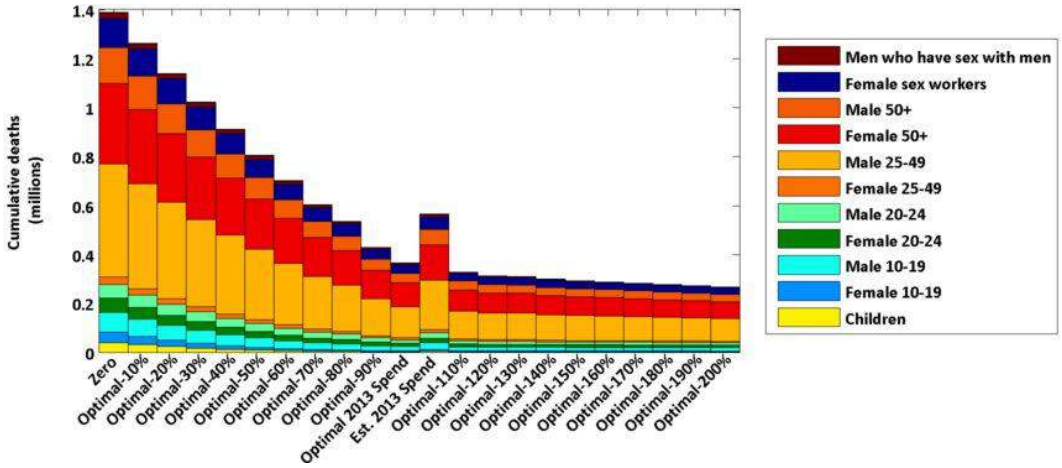
The small reduction in cumulative new HIV infections at optimal allocation of the current funding means that the current funding is already allocated close to optimal levels for preventing HIV incidence. The increases in AIDS deaths averted over the programme period come about because of savings from non-priority HIV programmes which allows more spending on the ART programme. If available spending fell to a level below that required to maintain the current number of people on ART resulting in withdrawals from other HIV programmes, there would be a sharp rise in HIV incidence particularly in children through increased mother-to-child transmission (**Figure 25**).

Figure 25 Cumulative new HIV infections (A) and cumulative AIDS related deaths (B) with current and optimal HIV resource allocation for different levels of HIV resource availability to minimise cumulative new infections and AIDS deaths, Zambia (2014–30)

(A)



(B)



Source: Optima model Zambia, using available epidemic and response data

As explained, the allocation of HIV resources and expected epidemiological outcomes changes with the amount of funding available. For example, if more funding becomes available and HIV programme spending were to double (200% of current levels) then new cases of HIV would further reduce to about 620,000 over the 17 years to 2030. **Table 5** summarises annual,

optimised expenditure levels for different HIV programmes at various levels of overall resource availability for impact over 2013–2030.

- As mentioned earlier, Zambia is a global success story concerning PMTCT, although it has come at a significant investment. Past investment in PMTCT has already reduced the incidence of mother-to-child transmission—the percentage of children born to HIV-positive mothers who become infected has fallen to 5.2% in 2013. According to our model projections, if PMTCT funding were reduced there would be a substantial increase in mother-to-child transmission over 2014–30.

Table 5 Optimal resource allocation levels to minimise HIV infections and AIDS deaths over 2013–30, and resulting cumulative HIV incidence and AIDS deaths (rounded to nearest 1,000)

Target population / programme	Estimated spending (2013)	Optimised 50% budget	Optimised 2013 budget	Optimised 150% budget	Optimised 200% budget
General adult BCC and condom programmes	$13,624,000	$0	$0	$17,328,000	$102,133,000
General youth BCC and condom programmes	$13,995,000	$0	$0	$0	$0
FSW and client condom programmes	$340,000	$0	$473,000	$9,329,000	$13,708,000
VMMC	$25,398,000	$0	$0	$53,249,000	$55,391,000
MSM condom programmes	$30,000	$0	$0	$0	$0
PMTCT	$22,317,000	$15,814,000	$22,317,000	$25,439,000	$28,811,000
HCT	$17,919,000	$0	$14,130,000	$35,167,000	$47,369,000
ART	$148,597,000	$105,296,000	$205,299,000	$222,816,000	$237,026,000
Cumulative HIV incidence	1,151,000	1,717,000	1,099,000	779,000	620,000
Cumulative AIDS deaths	565,000	365,000	804,000	293,000	269,000

5.2. Programme and Population Prioritization to Minimise HIV Incidence and AIDS Deaths at Different Funding Levels

From the optimal allocation results to minimise HIV incidence and AIDS deaths at different funding levels, we derive the following "investment cascade" in terms of funding for specific programmes (see **Figure 24**):

- Should less than 70% of current (i.e., estimated 2013) funding be available, funding should be prioritised to the ART programme and to some PMTCT programme activities, in order to continue providing treatment to the maximum number of ART clients and prevent AIDS death, and prevent vertical HIV transmissions.
- If between 70% and 100% of funding is available, PMTCT should be scaled-up and then ART provision should be expanded with HCT services getting more funding to diagnose additional PLHIV to support the ART expansion.
- As more funding than the current funding is available, the two proven interventions VMMC and FSW HIV prevention programmes (including ART for FSW) should be introduced for best impact in the 2013–30 time horizon. However, if a longer time horizon is applied in the analysis, investment in VMMC shows up as more important as its epidemiological impact can develop more fully (see following figure and full discussion in section 7.2). At the same time, the investment cascade recommends consolidation and further scale-up of ART and the commencement of scale-up of BCC and condom programmes for adults.
- Each of these HIV programme, including adult BCC and condom programmes, should then be scaled up further as more resources—above 160% of current funding—become available, as it is the adult population where there is a high number of new infections, but also advanced infections which require prevention and treatment interventions.
- Only at funding levels above 200% of current funding, do youth condom and BCC programmes become a priority. The youth also gain important and sustained HIV prevention benefits from the VMMC programme (VMMC uptake is across Southern Africa highest in adolescent boys and young men), and HIV positive youth gain treatment benefits through ART.
- Due to the small population size and small estimated contribution to overall incidence, MSM programmes are of less importance for minimising incidence and deaths within Zambia as a whole.

- Therefore, ART (including HIV testing) PMTCT, and VMMC (which is at service delivery level offered as a service package helping men to screen for HIV and other STIs and get linked to ART if treatment eligible) are the core programmes of the HIV response. Treatment not only saves lives and restores health but is also one of the few prevention approaches with effectiveness to reduce population-level transmission, if high levels of viral suppression are achieved.

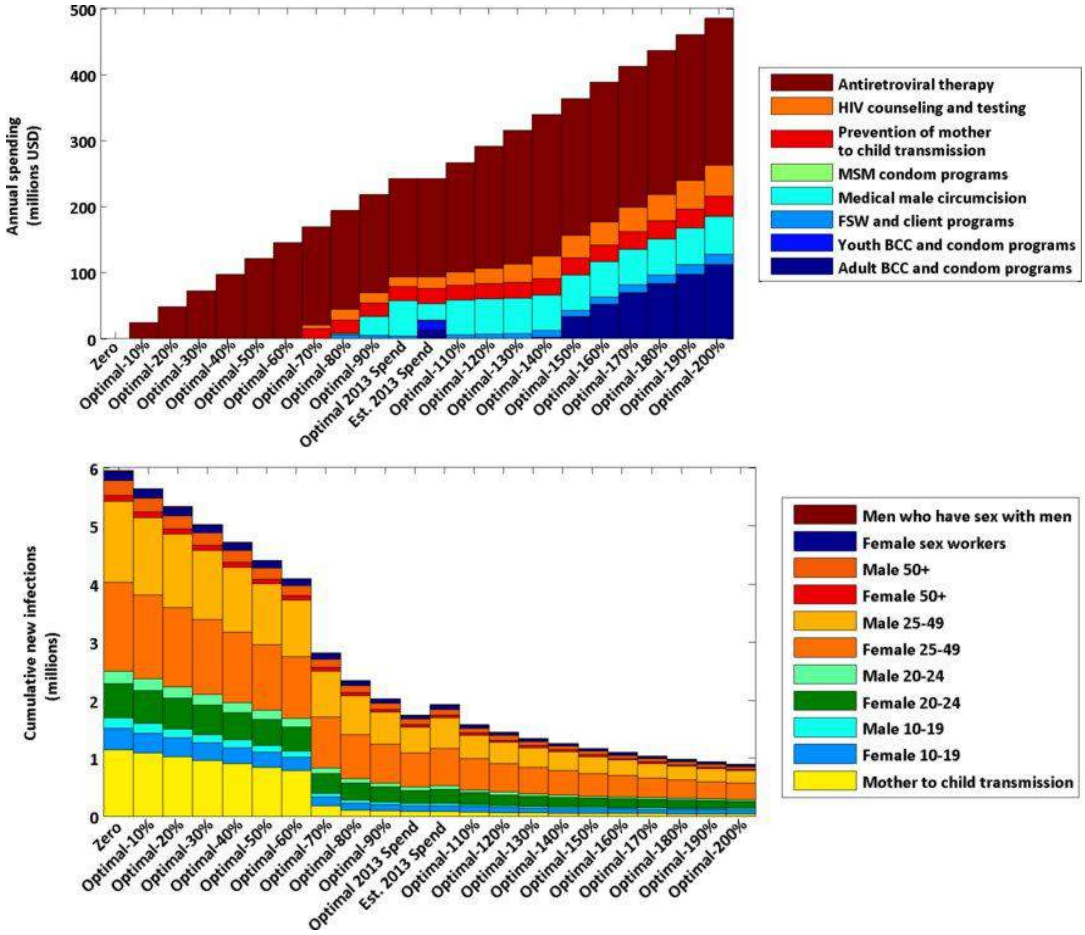
Investment in prevention of mother-to-child transmission of HIV must be maintained— PMTCT is one of the most cost-effective interventions and should be among the highest priorities for continued investment. It is a flagship programme in Zambia and our epidemic modelling suggested an approximately 85% decrease in vertical transmission since year 2000, which is mainly attributable to near-universal coverage of PMTCT. Eliminating mother-to-child transmission will provide numerous direct and indirect benefits to Zambia over the long-term. A relatively small amount of funding in required to maintain the current high coverage of PMTCT in Zambia.

HIV testing is essential to ensure PLHIV enter HIV care and treatment at the appropriate time. Surveys indicate an increase in HIV testing within the population over the last decade and this trend needs to be maintained in the future.

FSW and VMMC programmes are the core *traditional prevention* programmes of the HIV strategy.

- FSW and client prevention programmes are in all types of epidemics a top priority, as this population consistently has highest HIV incidence levels and partner numbers.
- VMMC is one of the most cost-effective and highly proven interventions for reducing HIV transmission. It is a once-off procedure and provides other STI-related and hygiene-related health benefits. However, the full HIV prevention benefits of VMMC take at least 25 years to fully develop.[19] This issue of allowing for a longer timeframe for VMMC to develop its full impact is important to understand. We therefore did an additional projection over 30 years. **Figure 26** presents the HIV resource allocation for different levels of HIV resource availability to reduce cumulative new infections and AIDS related deaths when **analysed over the period of 30 years.**
- The 30-year analysis suggests that more funding be allocated to VMMC under the optimal HIV spending compared with that of the current spending. It is the *immediacy* of ART and PMTCT in producing health impacts (reduced AIDS mortality, reduced incidence) which make these interventions attractive investments with quick returns. Immediacy of VMMC impacts are likely to be best if males are circumcised just before they enter their most sexually active period with high partner acquisition and high coital frequency.

Figure 26 Comparison of current and optimal HIV resource allocation for different levels of HIV resource availability to reduce cumulative new infections and AIDS related deaths, Zambia (2014–44)

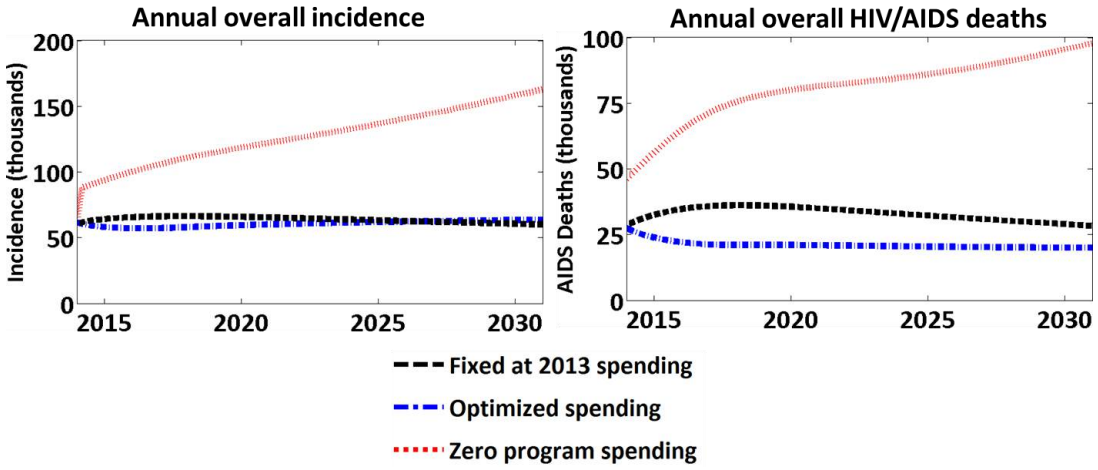


Source: Optima model Zambia, using available epidemic and response data

5.3. Change in Incidence and Deaths Over 2014–30

Our analysis produced time trends of HIV incidence and AIDS mortality under different allocation scenarios. **Figure 27** shows the change in annual incidence and AIDS deaths over time for the current spending allocation and the allocation minimising HIV incidence and deaths compared to a scenario where HIV programmes are completely withdrawn.

Figure 27 Time trends for annual HIV incidence and AIDS deaths, Zambia (2014–30)



It is predicted by Optima that HIV incidence and AIDS mortality will continue to decline if HIV investment levels are maintained—modelling of the HIV epidemic in Zambia suggests the epidemic will continue to decline into the future. Without the investment in HIV programmes, HIV prevalence and incidence in Zambia would increase substantially.

Not investing in priority HIV programmes has adverse impact on health outcome—if there were no funding for HIV prevention and treatment, the number of new HIV cases would increase to more than double current levels by 2030.

5.4. Efficiency Gains to Free Up Resources

Allocative efficiency considerations are tightly linked to those on implementation efficiency, as both approaches seek for best use of resources to produce health outcomes. We broadly distinguish efficiency in HIV programmes and in the HIV response management here.

5.4.1 Efficiency of HIV programmes

Two major HIV programme efficiency studies have been conducted recently, which provide insight into efficiency issues of HIV service delivery in Zambia: The assessment by the Institute for Health Metrics and Evaluation (IHME) and University of Zambia (UNZA) [20], and the assessment by the Zambia National HIV/AIDS/STI/TB Council (NAC) and World Bank.[21]

One highly relevant finding of the IHME/UNZA study was that ART patient volumes could significantly increase given facility resources in Zambia. The authors estimated that **Zambia has the potential to increase its average annual ART patient volume by 117%.** This means that the **marginal cost of additional ART patients may be lower, and that more health impact may be gained with limited additional resources**. The report points out that ART programmes are likely to be sensitive to quality time spent with clients, and negative effects, such as longer wait times, high rates of staff burnout and turnover, and compromised quality of care, need to be

avoided. The same assessment found that the **average facility cost per ART visit (exclusive of ARV costs) was relatively high in Zambia** compared to other countries. Each ART visit cost an average of 79 kwacha (US$15) to produce across facilities in Zambia, exceeding per-visit costs in Uganda (US$9) and Kenya (US$8), and coming in at a similar level to Ghana (US$16). The same source reports that the visit costs of ART patients incurred by Zambian facilities were much lower for established patients, largely driven by the lower frequency of visits and tests compared to new patients. In comparison with the other two countries, Zambian facilities recorded a higher average annual cost per ART patient, excluding ARVs (US$86), than Uganda (US$53) and Kenya (US$52). Equally, Zambia had the highest average cost per ART patient if ARVs—the main cost driver—were included (US$266). According to the report, some if this was due to the consistently higher prescription rates of tenofovir-based regimens at ART initiation, one of the more expensive ARVs, compared to Kenya and Uganda.

These findings, and the high variation in per-visit costs across Zambian facilities, suggest that **efficiency gains may be possible and needed as the ART programme expansion continues**. Another finding was that across platforms, the majority of HIV patients spent more time waiting for health services than travelling to receive them. However, HIV patients were overall quite satisfied with the care they received.

The NAC/World Bank study conducted in 2013 complements the picture including data on client satisfaction with services. In addition, it highlights issues around health care staff motivation to deliver HIV services. Only 22% (57/264) of all personnel rated their motivation to provide ART as being either high or very high (higher for medical doctors at 54%). Similarly, general staff motivation was low for HCT at 22% and for PMTCT at 24% (medical doctors: 67% and 84%, respectively). Close to half of all staff had low or very low motivation (47% for ART, 48% for HCT, 44% for PMTCT). This low level of staff motivation did however not translate into negative client experiences. The majority of clients were satisfied or highly satisfied with various aspects of care: 90% (162/180) with the attitude of staff, 82% with the time spent with the health staff, 74% with the opening hours of the health facility, 71% with the waiting time before the client was seen by a health service provider, 85% with cleanliness of the health facility, 97% with privacy during consultation, and 92% with the medical follow-up services. Importantly, **95% (86/91) of ART clients were satisfied or highly satisfied with the ART services they received**. Concerning the efficiency of ordering and supply systems, the picture was mixed. While 48% (19/40) of in-charge staff at health facilities 'always received' the medicines ordered in a period, 8% of in-charge staff 'almost never received' the medicines ordered. This problem was slightly more prominent at health centres and first level/district hospitals. Seventy-three percent of in-charge staff and 87% (143/165) of care providers felt that **the supply of ARVs was generally better**. Sixty-five percent (115/178) of clients were either very satisfied or extremely satisfied with the availability of medicines.

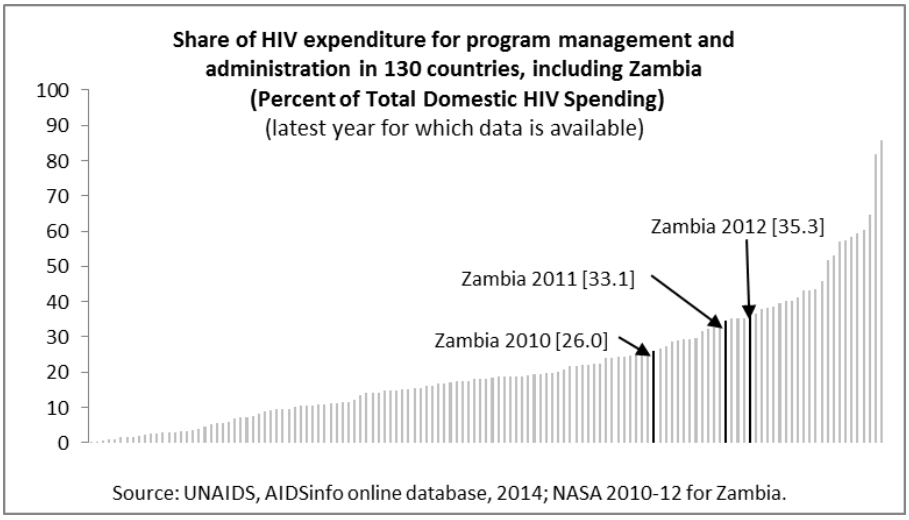
These data illustrate that many of Zambia's health facilities have sub-optimal efficiency and could be more productive. The World Bank-supported Health Services Improvement Project launched in 2014 is one of the initiatives to strengthen efficiency in the Zambian health service delivery system. The support project has a focus on maternal, newborn and child health and nutrition services. Shortages of key inputs that are necessary to deliver the defined package of basic health services will be addressed through increased availability of skilled frontline and community health workers, increased availability of critical drugs and commodities, and enhanced supervisions from higher level. By putting the key elements together at the same time and in the same location, **more facilities will be pushed to the production function frontier, and therefore, deliver better services to the extent possible at a given cost**. The project will also contribute to **improvement of allocative efficiency** at health facilities and community levels. It focuses on primary health care with active community participation as a cost-effective modality to provide a package of high impact services.

A costing study supported by Health Policy Project on paediatric ART also provided very interesting findings.[22] The study reported that the average annual incremental cost of providing paediatric ART services in Zambia was US$220. By facility type, the incremental cost was **highest at rural health centres (US$260), followed by hospitals (US$228), and urban health centres (US$176).** Cost drivers varied by facility type. Across all types of facilities, drugs, consumables, and medical supplies comprised roughly one third of treatment costs; staff training comprised 26% of the cost; overhead costs 23%, vehicles and equipment 13%, and direct staff costs 5% of total cost. The average incremental cost of paediatric ART services was lower than the combined cost of paediatric ART services and other infant and child services estimated in a previous study. This work therefore demonstrated that **it is less costly to add paediatric treatment to existing treatment sites than to offer treatment through sites that only serve children**.

5.4.2 Efficiency in HIV response management and administration

Compared to other countries, Zambia allocates a significant share of HIV expenditures for programme management and administration. More than a third (or 35.3%) of the total HIV investment was spent on programme management and administration in 2013, which was increased from 26% in 2010 (**Figure 28**). There is an opportunity to explore further any efficiency gains which could be made in the management and administration of the HIV response which could then be reallocated to priority programmes for achieving greater health outcomes with the same level of overall funding.

Figure 28 Share of HIV expenditure for programme management and administration, 130 countries



Therefore, programme management costs currently consume a significant amount of national AIDS resources in Zambia and if savings can be made then the funding can be reallocated to HIV programmes for greater impact.

We estimated that by reducing programme management costs by 20% and increasing money available for HIV prevention and ART (by approximately 10%), efficiently allocated HIV programmes could prevent 139,000 more infections until 2030, corresponding to a 12% reduction in new infections compared to current spending allocations.

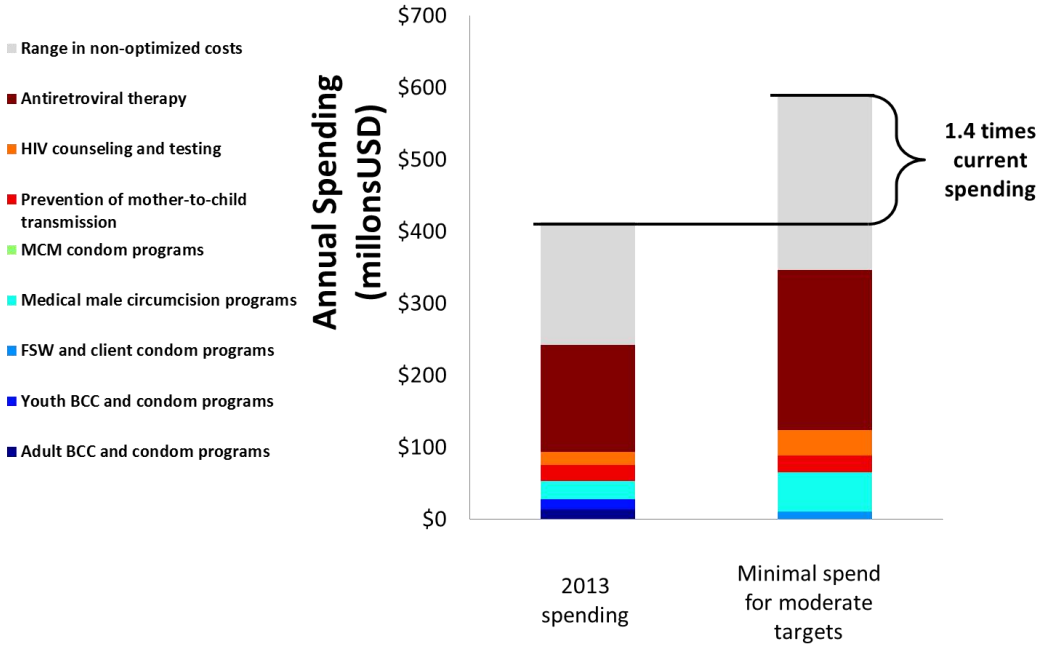
CHAPTER 6. PROJECTED COST AND FINANCIAL COMMITMENTS

6.1. Cost to Achieve National Strategy Targets

To achieve moderate targets by 2030 requires an increase in annual spending—using our optimisation analysis, we calculated that the minimal spending required on HIV programmes to achieve the R-NASF's moderate objectives is 1.4 times current spending (**Figure 29**). However, improvements in technical efficiency and economies of scale could reduce indirect costs and the overall amount of funding required.

Scale-up especially of VMMC and ART, but also PMTCT, is required to achieve the moderate objectives efficiently (**Figure 29**).

Figure 29 Additional spending required per annum for achieving moderate targets in Zambia over 2014–30



The changes in annual spending levels required to achieve the moderate targets are presented in **Table 6**. A doubling of spend would show as a 200% change. The largest percent increase would be required for FSW programmes at nearly 30 times more spend.

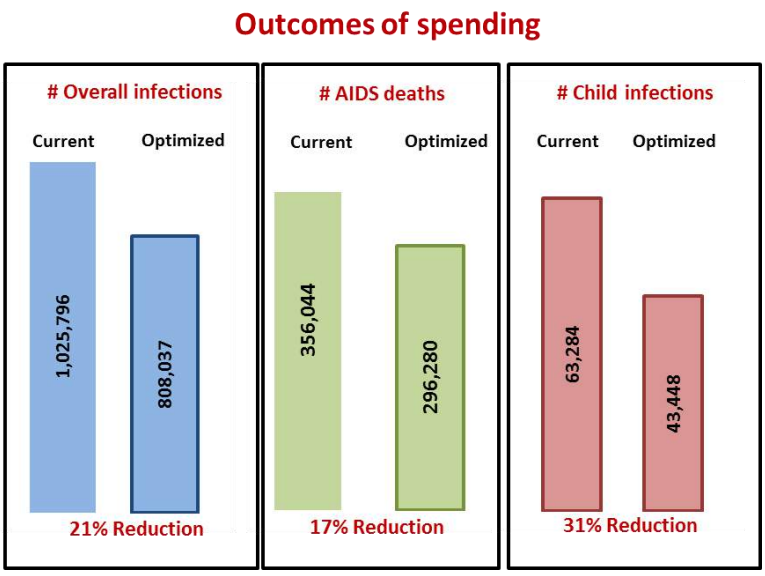
Table 6 Changes in estimated expenditure levels to achieve moderate targets, by spending category, Zambia (rounded to nearest 1,000)

	2013 spending	Minimal spend for moderate targets	Percent change from 2013
Adult BCC and condom programmes	$13,624,000	$0	-100%
Youth BCC and condom programmes	$13,995,000	$0	-100%
FSW and client condom programmes	$340,000	$10,190,000	2,993%
Medical male circumcision programmes	$25,398,000	$55,396,000	218%
Condom programmes	$30,011	$0	-100%
Prevention of mother-to-child transmission programme	$22,316,604	$22,954,000	103%
HIV counselling and testing	$17,919,322	$35,263,000	197%
Antiretroviral therapy	$148,596,560	$222,570,000	150%
Range in non-optimised costs*	$170,930,478	$244,431,000	143%
Total	**$413,149,329**	**$590,804,000**	**143%**

* As per table 2—Care and support for people living with HIV, programme management and administration, human resources, social protection and social services, enabling environment, research.

By increasing spending to achieve the moderate objectives by 2030, 220,000 more HIV infections, 60,000 more deaths, and 20,000 more mother-to-child transmissions would be averted in Zambia (**Figure 30**).

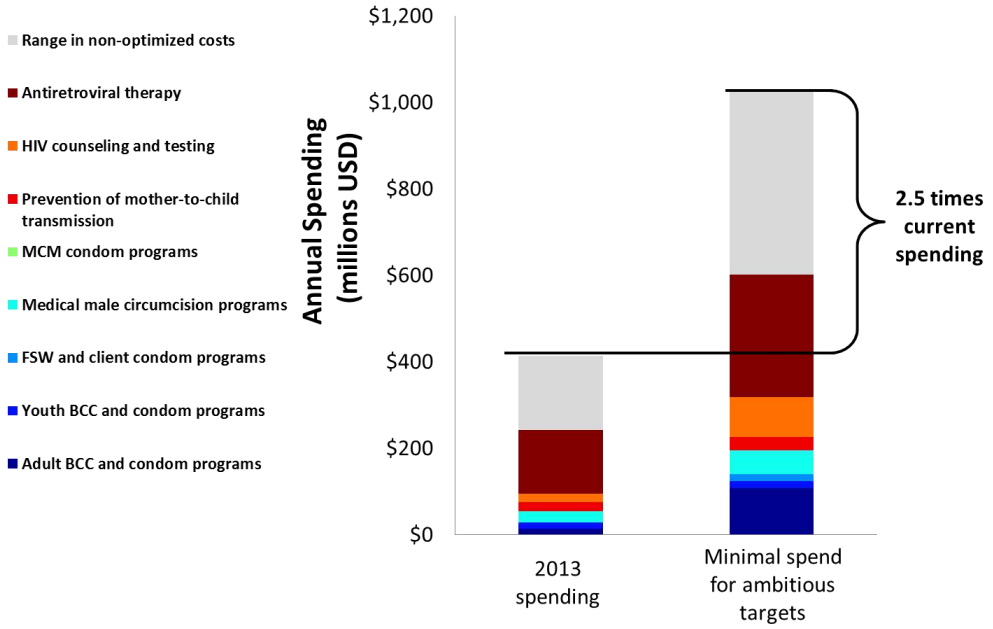
Figure 30 Outcomes of filling the moderate funding gap in Zambia over 2014–30



To achieve ambitious targets by 2030 requires a substantial increase in annual spending—using our optimisation analysis, we calculate that the minimal spending required on prevention and treatment programmes to achieve the R-NASF's ambitious objectives is 2.5 times current spending (**Figure 31**).

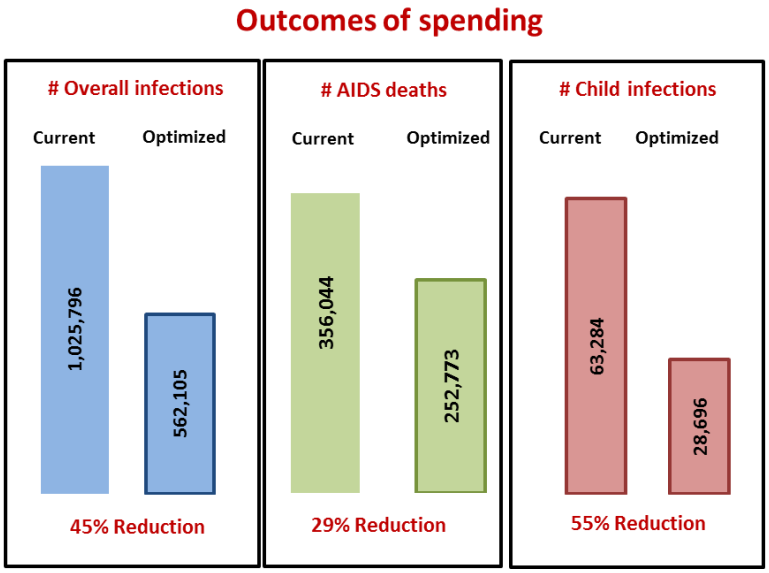
Scale-up in spending for all HIV programmes is required to achieve the realistic objectives efficiently, particularly prevention programmes, VMMC, HCT, and ART (Figure 31).

Figure 31 Additional spending required per annum for achieving ambitious objectives in Zambia over 2014–30



By increasing spending to achieve the ambitious objectives by 2030, 460,000 more HIV infections, 104,000 more deaths, and 35,000 more mother-to-child transmissions would be averted in Zambia (**Figure 32**).

Figure 32 Outcomes of filling the ambitious funding gap in Zambia over 2014–30



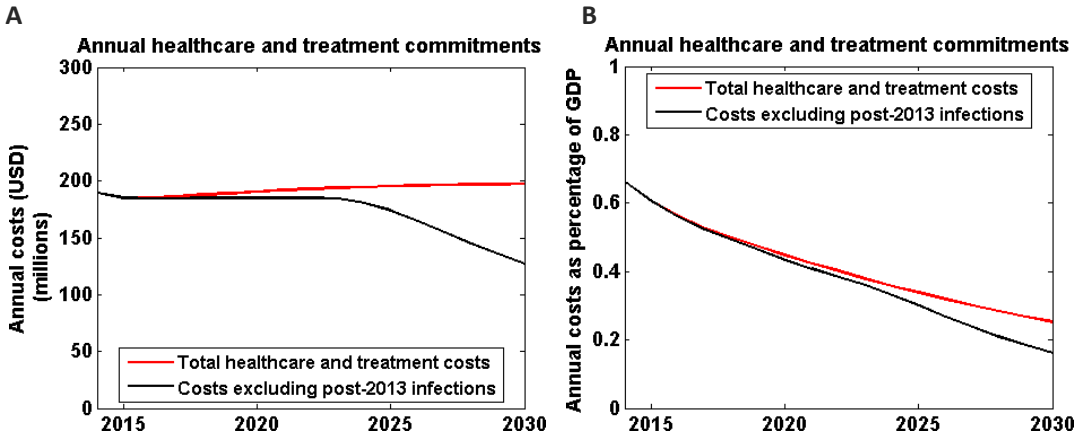
6.2. Long-term Financial Commitments for HIV Services for People Living with HIV

6.2.1 Future treatment and healthcare costs caused by HIV infections

The forward projection of costs of HIV services for PLHIV was done in absolute financial terms and in terms of share of GDP. It was projected that if the number of people on ART is maintained at 2013 (termed 'current') levels, then future costs of providing healthcare and treatment will slowly rise as new HIV infections continue to occur and people currently on first line ART transition to second line therapy.[8]

The majority of these financial commitments over 2014–30 are due to infections prior to 2014 (**Figure 33**). This means future commitments are locked in by past HIV infections and even if HIV incidence reduced substantially the fiscal liability will largely persist. The contribution of HIV infections prior to 2014 starts to decline after 2025 due to mortality within PLHIV.

Figure 33 Projected future healthcare and treatment commitments, Zambia (2014–30)

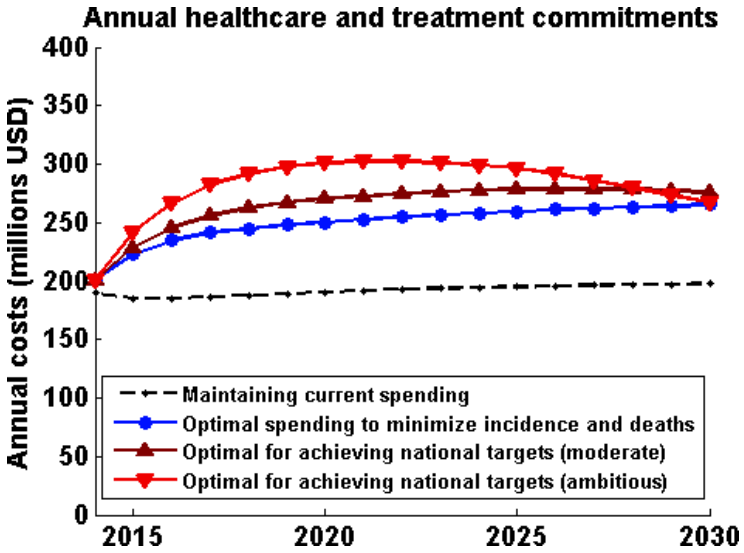


Notes: Red line = total future commitments; black line = commitments due to HIV infections occurring prior to 2014 (annual costs are undiscounted and in 2013 US$); **A** = Projected future commitments for the current scenario where prevention and ART spending is maintained at the current allocation; **B =** Projected future commitments as a share of GDP.

To achieve the desired epidemic objectives will increase costs of providing healthcare and ART to PLHIV in the future, as ART coverage increases to reduce mortality (**Figure 34**). The ambitious objectives result in an immediate increase in future costs but these costs reach a peak before 2025 and then start to decline—so much so that the costs in 2030 for the ambitious targets are less than the costs for the moderate targets. This is due to the large projected decrease in incidence after 2014 and a corresponding reduction in people initiating ART during 2014–30. While the costs or financial commitment for the policy targets does not constitute a formal debt, it nevertheless absorbs current and future financial resources.

[8] The optimisation analysis maintained the level of spending allocated to ART to ensure current ART clients can remain on treatment, and three unit costs were used (for healthcare, first line ARVs and second line ARVs).

Figure 34 Annual costs for providing ART and healthcare to people living with HIV over 2014–30 for optimal spending scenarios, Zambia



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CHAPTER 7. CONCLUSIONS

7.1. HIV Epidemic and HIV Programme Response Trends

Future of the HIV epidemic in Zambia if no changes were made to current approaches: Thirty years after the first HIV case was diagnosed in Zambia, the HIV epidemic has consolidated at a high level and consumes about 1 of every 5 health dollars. Burden of disease estimates show that AIDS was the leading cause of premature death in Zambia in 2010. The toll is enormous in people aged 20–50 years, where one in every two years of life lost is due to HIV. The number of new HIV infections is projected to stabilise at high levels. Until the DHS 2013–14 data can be used to update the projections, there is much uncertainty in epidemic projections. With the available epidemiological data and if current funding volume and allocations are maintained, Spectrum and Optima project a levelling off of new HIV infections at approximately 60,000 per year until 2030.

HIV prevention efforts amongst key populations are hampered by a lack of data: The two key populations FSW and MSM have, according to Optima outputs, high HIV incidence rates at 4.0% and 2.5%, respectively, but these estimates equally lack recent empirically measured data. The forthcoming survey data (Panos study on FSW and MSM; Population Council study FSW, MSM and IDU) are urgently required to appropriately model these key populations' epidemics and programme targeted service delivery.

Zambia is a global success story in terms of PMTCT and has almost achieved eMTCT targets: The decrease in vertical transmission is a key achievement in Zambia. Optima estimates over 25,000 mother-to-child transmissions in 2000, and only about 4,000 in 2013, a reduction of approximately 85%. One of the statistics illustrating the comprehensiveness of Zambia's PMTCT programme is the comparatively high level of early infant HIV diagnosis—in 2013, 72% of infants born to HIV positive mothers received a virological test for HIV within 2 months of birth (leaving however about 25,000 infants per year not diagnosed). Another milestone in Zambia's HIV epidemic is the development of a national male circumcision programme, which has seen exponential growth in procedures achieved, stimulated innovation in service delivery, and now needs to catch up to meet coverage and impact targets (if rapid, 80% VMMC scale-up occurred, PEPFAR modelling predicts that VMMC could reduce HIV incidence in Zambia by 30% between 2011–25). [23]

There has been important research around routinising paediatric HIV diagnosis based on the provider-initiated HIV counselling and testing (PICT) roll-out in Livingstone General Hospital.

[24] Among in-patient children eligible for PICT, 98.5% were counselled, 98.2% HIV tested, 15.5% found HIV-positive, and 99.3% of these enrolled in HIV care, including initiation on co-trimoxazole prophylaxis. Operational lessons included the placement of full-time nurse counsellors at key areas of paediatric intake with capacity to draw specimens, task-shifting to peer counsellors in the wards, a bolstered ARV supply chain, a package of on-site HIV services, and follow-up care for children and families.

In the past decade, significant strides in HIV programme roll-out and decentralisation have been made: Zambia's health providers have succeeded at bringing the services closer to the people. Several HIV programmes have been effectively rolled out and decentralised. By 2012, there were 564 ART sites, and there were 287 VMMC sites by end 2011. Equally, the number of HCT sites increased from 56 in 2001 to 1,800 in 2012 and a home-based VCT model was found to be feasible, highly accepted and to have important effects on equity in uptake in a rigorous cluster-randomised trial in southern Zambia. [25] Decentralisation also means clients' opportunity costs such as transport fees decrease, as found by in the recent assessment of health facility performance by IHME/UNZA. [26]

Zambia has also made significant strides in increasing ART and VMMC coverage: By end 2013, a total of 580,118 people were receiving ART and the officially reported ART coverage was 81.9%. The HIV treatment cascade is supported by specially trained health personnel, with CHAs performing HIV testing, HIV nurse practitioners initiating PLHIV on ART, and general nurses maintaining treatment. Regarding VMMC, by end 2013 a total number of 635,458 men had volunteered to be medically circumcised. This translated into 33% achievement of the 80% coverage target, and put Zambia in third place among the VMMC priority countries, after Kenya and Tanzania (which both had relatively high levels of pre-existing male circumcision). Based on a task shifting policy, clinical officers and nurses are now able to conduct VMMCs, and other measures like VMMC campaigns and outreach support the scale-up.

Current HIV programme funding allocations are optimal for reducing the most new HIV infections: The modelling analysis conducted in this report found that recent HIV prevention impact has been substantive, as resource allocation was geared towards minimising new infections. The Optima analysis finds that Zambia's HIV resource allocation pattern in 2012/13 may have been close to optimal for best HIV incidence reductions in a 15-year time frame and that the most important improvements that can be made to current HIV funding allocations would be to allocate more funding to ART to avert more AIDS deaths. This is a useful insight for policy makers, and implies that for the number of new HIV infections in Zambia to reduce to below the current projected level of 60,000 per year, more funding will be needed to further scale-up the HIV response.

7.2. How the HIV Response in Zambia can be Improved in Future

Although Zambia has shown remarkable improvements and strides in addressing HIV, there is room for improvement. This report has specifically identified five areas in which the HIV response can be improved:

First, improve the technical efficiency and reach of HIV programmes: Technical efficiency gains would free up resources which could be used elsewhere, increase health production and make Zambia's HIV response more sustainable. The country has evidence from efficiency assessments where savings could potentially be made, for instance in the reduction of facility cost per ART visit. The procurement and distribution costs of HIV programme commodities represent a large part of the HIV budget and in turn of service unit costs. Continuous supply chain analysis and strengthening as well as seeking out of best commodity prices remain essential, especially as priority programmes scale-up further. A very large proportion of the total HIV response budget is spent on management and administration of the national HIV response (over a third in last NASA year). We estimated that reducing programme management costs by 20% and reinvesting these savings in priority HIV programmes could prevent 139,000 additional HIV infections until 2030. This would correspond to a 12% reduction in new infections compared to current spending allocations.

As the ART programme evolves further and the B+ PMTCT option is being planned, piloted and seeing early implementation, [27] **understanding non-adherence to ART is crucial to make ART investments work**. A focus on analysis of the HIV care cascade needs to include diagnosis of non-adherence to ART of the different client groups including B+ recipients, discordant couples on early ART, etc. The cohort study on the effects of clinic-based food assistance for ART clients in Lusaka is a step in this direction. [28] The research showed significantly improved ART adherence after six months among food assistance recipients, with best incentivising effects among patients recently initiated on ART, those with poor nutrition, or advanced disease. In general, there is a need for excellent ART service data and strong data analysis along the whole HIV care cascade. The IHME/UNZA efficiency assessment concluded that *"health facilities are positioned to support Zambia's goal of providing universal access to HIV treatment and care".* The same study reported significantly higher average annual cost of treating ART clients at hospital level compared to decentralised provision at rural health centres. As the volume of individuals seeking chronic care, and entering long-term follow up, is increasing, further gains in efficiency of chronic care will be essential. This can for instance include down-referral of

stable ART clients to the community level, and the establishment of alternative medicine delivery systems to decongest health facilities.

Second, allocate HIV resources efficiently to achieve best impact: A core finding is that ART, PMTCT and VMMC are the most important programmes (with HCT supporting ART) for optimising the impact of current levels of HIV investment. Since most of the analyses were run over a 15 year time horizon only, ART tended to dominate the optimal allocation scenarios for both HIV incidence and AIDS death reductions. However, model outputs suggested practically identical HIV prevention benefits arising from ART (TasP effect) and VMMC, with the exact ranking largely depending on assumptions around VMMC and ART unit costs and population-level effectiveness (see **Table 9** for all the values used for the model constants).[9] A detailed VMMC modelling analysis in South Africa by World Bank demonstrated that the full impact of VMMC on HIV incidence takes about 25 years to develop, and it is the immediacy of ART and PMTCT effects which make these interventions attractive for obtaining health impact rapidly. [29] Our analysis of impact of optimal allocations over a 30 year time horizon then confirmed that VMMC shows up as an excellent investment if the full HIV prevention effect of VMMC is given sufficient time to develop. We conclude that focusing spending on the continued VMMC scale-up would be the best *investment* strategy for minimising HIV incidence in the *long-term*. Although ART has a high potential to avert both AIDS deaths and new infections through the TasP effect, we caution against switching to a TasP-dominated prevention approach while VMMC can be further scaled-up. VMMC brings males to use HIV services as the procedure is offered with HIV and STI screening and linkage to care of men with a positive diagnosis. VMMC also helps to achieve the globally promoted 90-90-90 vision through directly and sustainably preventing HIV infections in men and indirectly in women and babies. A large and maturing ART/TasP programme will increasingly incur additional costs for second line treatment (US$580 vs. US$280 for first line in this analysis), require effective client-specific ART adherence interventions, [30] and see healthcare costs accruing in the aging ART cohort.[10]

In addition, we conclude based on model outputs that there should be little change in allocations to HCT, which is required to identify PLHIV in need of ART, and to the PMTCT programme, which is responsible for the large drop in MTCT and uses a relatively small proportion of the HIV response budget while maintaining the low level of MTCT. In the provision of HCT, emphasis should be on targeting of the testing effort based on programmatic

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[9] For example, if the reduction in infectiousness through ART is reduced to 65% (from our assumed 70%) then the optimisation process will immediately prefer resource allocation to VMMC over ART.

[10] For instance, the Zambia STEPS survey found 39% of participants overweight or obese, and the latest statistics from South Africa attribute an increase of obesity to ART scale-up, among other factors.

research evidence, such as Mutanga's study on PICT in children which showed a high yield of HIV positivity *and* very high linkage to care. Data on HIV infection risk, such as the forthcoming HIV incidence and prevalence data derived from the DHS 2013–14 samples, also need to be closely examined for profiling of individuals who should be prioritised for HCT, as the country moves towards implementation of the global 90-90-90 targets.

As this analysis optimised resource allocations to the highest-impact interventions, BCC and condom promotion programmes for adults and youth were not prioritised at likely resource availability levels. These populations are however targeted by other interventions, such as the Ministry of Education-provided IEC/BCC in the school curriculum, the SRH and PMTCT interventions by MOH and civil society organisations, the VMMC prevention package for males, the key population prevention packages (targeting youth and adults in hot spots), and the HCT/ART programme for PLHIV. At higher resource levels, and if other HIV interventions were added into the analysis (such as cash transfers for young women, or pre-exposure prophylaxis), the resource allocation results of the model would likely include targeted programmatic investments for adults and youth too.

Third, mobilise additional domestic resources: Zambia is in a group of countries with high dependency on external HIV funding—an artefact of Zambia's historical LIC status until 2012. While Zambia's government expenditure on health is relatively higher than in other comparable countries, the domestic HIV spending as a share of total HIV expenditure is very low. In 2012, Zambia received US$ 264 million from external sources for its HIV response (93% of total HIV spend) and contributed itself US$15.8 million according to NASA data. This represents only 1.8% of Zambia's public sector expenditure on health. Considering the economic growth data of Zambia, there is potential to increase the HIV contribution in line with ability to pay and disease burden. A continuous dialogue on how Zambia can develop domestic HIV funding streams while improving HIV programme performance is essential. This dialogue will need to take into account the continued need for a multisectoral response which leverages resources from other sectors and line ministries, and provides progress in other HIV/AIDS-relevant areas such as education, sanitation and poverty alleviation. Cost sharing mechanisms across line ministries can be explored to foster greater domestic investment beyond the health ministry.

HIV/AIDS requires considerable resources, not least because of the heavy public sector subsidy for HIV services. We showed that in contrast to health services in general, the out-of-pocket and household contribution to HIV service provision is low. The government policies of free access to HIV prevention and AIDS care and treatment mean that Zambians have financial protection from the catastrophic effects of HIV and AIDS medical costs. This protection is a

cardinal importance in a country where over 60% of people live below the national poverty line, and income is highly skewed with 20% of income shared by 70% of the population.

Fourth, better plan for and predict programme financial sustainability: Increased domestic financing needs to be provided in sustainable and at predictable levels. At high external dependency levels, it is particularly difficult to predict future funding levels for health programmes. In Zambia, the percentage of *externally financed* health expenditure in the last decade varied by a factor of 3 (ranging from about 15% to about 45% of total health expenditure). Large variations in public spending on health can equally be problematic for programme sustainability. In the years 2007 and 2009, domestic spending for health decreased substantially from the respective previous years, illustrating the fluctuating nature of domestic funding. If much of the HIV response was funded from domestic sources with poor predictability, the sustainable provision of ART could be at risk.

This report looked at annual HIV prevention and healthcare financing commitments as a function of the impact targets pursued by the national HIV strategy. Optima projects commitments for the moderate and ambitious scenarios which cost in addition about US$20 million and US$50+ million per year, respectively, compared to optimised spending based on 2013 resource levels. Therefore, the country would need considerable additional and sustained HIV investment to pursue these HIV incidence and AIDS deaths reductions successfully.

The issue of sustained HIV funding needs is also illustrated by our result that a large part of future spending commitments up to 2030 is determined by existing HIV infections. It is only post-2025 that the projected costs of existing HIV infections start to fall substantially, due to mortality among PLHIV. However, projected total annual commitment remains at considerable levels throughout this time horizon, peaking at nearly US$300 million in about 2018 and remaining at nearly US$ 250 million by 2030, according to Optima projections. It is estimated by Optima that currently annual health care and treatment costs amount to about 0.6–0.7% of GDP, and that this percentage will fall to approximately 0.3% of GDP by 2030.

Fifth, intensify programmes for key populations at high risk through allocation of additional resources to gain coverage, scale and impact: FSW-oriented programmes also showed up as important in our optimisation analysis and should receive about 2% of current HIV response funding. This makes epidemiological sense as this population has the highest HIV incidence rate and appears to be underserved currently. We conclude that spending on FSW services should be increased until coverage reaches its maximum level and very high levels of condom use are achieved in paid sex. MSM programmes did not show up in the optimisation due to the small size of the MSM population. This does however not mean that specialised providers should not offer high quality adapted services for this vulnerable and underserved key population.

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TECHNICAL APPENDIX

Technical Appendix 1. Data Collation and Synthesis

To perform our optimal allocation analyses for Zambia required a large amount of data describing the HIV epidemiology, population demographics, acquisition-related behaviour, clinical characteristics, and HIV programme and health costs. We collated data from all available publications, documents, reports, and data files provided by Zambian stakeholders.

1.1. Sources of Data

The following key references were the primary sources of data used in the analysis:

- Zambia Demographic and Health Survey 2007. Central Statistical Office (CSO), Ministry of Health (MOH), Tropical Diseases Research Centre (TDRC), University of Zambia, and Macro International Inc. 2009. Zambia Demographic and Health Survey 2007. Calverton, Maryland, USA: CSO and Macro International Inc.
- 2012 UNGASS Report. Zambia Country Report: Monitoring the Declaration of Commitment on HIV and AIDS and the Universal Access. Biennial Report. Zambia National AIDS Council 2012.
- Zambia Sexual Behaviour Survey 2009. Central Statistical Office (CSO), Ministry of Health (MOH), University of Zambia, and MEASURE Evaluation. 2010. Zambia Sexual Behaviour Survey 2009. Lusaka, Zambia: CSO and MEASURE Evaluation.
- Zambia HIV Prevention Response and Modes of Transmission Analysis. Zambia National AIDS Council and UNAIDS 2009.
- Zambia 2010 Census of Population and Housing. Central Statistical Office. 2012.
- 2013 Spectrum (EPP and GOALS) and Modes of Transmission model inputs and epidemiological outputs. Spectrum workshop October 2013.
- National AIDS Strategic Framework 2014–2016 working documents.
- Direct communication with Clinton Health Access Initiative (CHAI) staff in Zambia.

1.2. Data Synthesis

From all the data collected, we synthesised relevant data to obtain best point estimates and uncertainty ranges for all the parameters used in our modelling evaluation. We collated data over the period 2000 to 2013. We merged multiple sources using basic calculations and

statistical techniques. Usually, due to limited data, we used a simple weighted average of data from individual studies. However, for many indicators we only collected a single datum value, which we assessed for quality and specified an assumed uncertainty range (usually ± 25%). The resulting data estimates are stored in a single *Optima* input file as a Microsoft Excel file (Zambia-Optima input spreadsheet.xlsx). We used this file for our modelling analysis.

1.3. HIV/AIDS Programme Spending Data

We obtained estimates for the cost of previously introduced HIV prevention programmes and administration costs using a "top-down" approach—estimating the total overall expenditure to implement a programme in Zambia. Our primary sources for programme spending were the Zambian National AIDS Spending Assessments (NASA) and unit cost data provided by CHAI. We allocated HIV/AIDS spending over 2000–12 into spending for HIV prevention and treatment programmes and other indirect or essential costs.

1.4. Allocation of HIV Funding to HIV Prevention and Treatment Programmes

Using available HIV funding, spending and budgeting data for Zambia we identified core prevention programmes and estimated the total funding allocated to programme in 2013 (representing current spending). We considered funding for eight prevention and treatment programme categories with the remaining spending going towards indirect or other costs (see main document). The final programme categories used in our allocative efficiency analysis:

- Behaviour change and communication (BCC) and condom promotion for general population males and females aged 10–24 years.
- BCC and condom promotion for general population males and females older than 25 years.
- Prevention for female sex workers (FSW) and their clients
- Voluntary medical males circumcision (VMMC)
- Prevention for men who have sex with men (MSM)
- Prevention of mother-to-child transmission (PMTCT)
- HIV counselling and testing (HCT)
- Antiretroviral treatment (ART) for diagnosed people living with HIV

Total spending estimates on VMMC and ART for 2013 were calculated using unit costs provided by CHAI multiplied by the estimated number of people receiving treatment. Spending on all other programmes for 2013 was estimated using the 2012 NASA data. We did this through a

multi-step process. First, we converted NASA spending estimates in Zambian Kwacha to US dollars the exchange rate (equal to 5.15 Kwacha for 1 US$ in 2012). We then allocated each category of spending in the 2012 NASA to a specific programme or combined spending category. We then split funding for broad prevention categories, unclassified funding, or categories targeting multiple population groups in proportion to population size or the number of PLHIV in each population and reallocated it to the appropriate prevention or treatment programme. Finally, we assumed an average annual inflation rate of 7% to obtain 2013 spending estimates from the 2012 values. The main document provides the final estimates of 2013 spending for each HIV/AIDS programme used in our analysis. All spending data and 2013 allocation estimates are provided separately in the Microsoft Excel file Zambia-Budget and Funding Spreadsheet.xlsx.

1.5. Modelling Methodology

1.5.1. Mathematical Model – Optima

To assess HIV epidemic trends, resource needs, and the allocative efficiency of current spending , we used the Optima model [9]. This model contains a detailed mathematical model of HIV transmission and disease progression. Optima is sufficiently flexible to track the HIV epidemic over time to produce long-term forecasts, and to allow us to conduct allocative efficiency analyses. Optima uses best-practice HIV epidemic modelling techniques and incorporates realistic biological transmission processes, detailed infection progression, and sexual mixing patterns and drug injection behaviours. Optima describes the impact of HIV programmes indirectly through their influence on behavioural and clinical parameters.

The model distinguishes people who are undiagnosed, diagnosed, and on effective anti-retroviral therapy (ART). Diagnosis of HIV-infected individuals occurs based on a HIV testing rate dependent on CD4 count and population type. Similarly, diagnosed individuals initiate ART at a CD4 count dependent rate. The model tracks those on successful first- or second-line treatment (who have an increasing CD4 count) and those with treatment failure.

We used Optima to calculate the change in HIV incidence and HIV/AIDS-related deaths due to changes in funding and the cost-effectiveness of HIV prevention programmes in Zambia. Optima is sufficiently flexible to track epidemics and behavioural parameters over time in Zambia, to produce long-term forecasts, and to conduct allocative efficiency analyses.

1.5.2. Population groups and Transmission Pathways for Zambia

Within Optima, the overall Zambian population is partitioned by risk-group and health state. Individuals are assigned to a given population based on their dominant risk; however, to

capture important cross-modal types of transmission (relevant behavioural parameters can be set to small but nonzero values (e.g., a proportion of MSM are bisexual).

For the Zambia Investment Casework we evaluated the generalised HIV epidemic in Zambia using the following population groups:

- Female children aged 0–9 years
- Male children aged 0–9 years
- Females aged 10–19 years
- Males aged 10–19 years
- Females aged 20–24 years
- Males aged 20–24 years
- Females aged 25–29 years
- Males aged 25–49 years
- Females aged 50+ years
- Males aged 50+ years
- Female sex workers (FSW)
- Men who have sex with men (MSM)

For the purposes of programme spending allocation, we label males and females aged 10–24 as youths and males and females older than 25 as adults.

There is a concern of a growing HIV epidemic amongst people who inject drugs (PWID), particularly in Lusaka. One of the objectives of this analysis is to include HIV transmission through shared injecting equipment given data availability. However, there was insufficient data to include this population. Injecting drug use is happening in Zambia on a small scale, but there are no data on the size of the drug user population, the frequency of drug injection or sharing of injecting equipment (2007 MOT report and 2012 UNGASS report).

We assume HIV transmission between these populations only occurs through sexual partnerships. To reflect the sexual partnership age gap males have sex with females in the same age group and females in the immediately younger age group. We assume sex workers have clients from the male 20–24, 25–49, and 50+ populations. We assumed MSM do not have commercial acts with all male partnerships covered by regular and casual acts. However, there is evidence MSM have sexual partnerships with females. Thus for MSM we use other sexual acts to represent MSM-female sexual partnerships. Regional data, including Zambia, (CEDEP

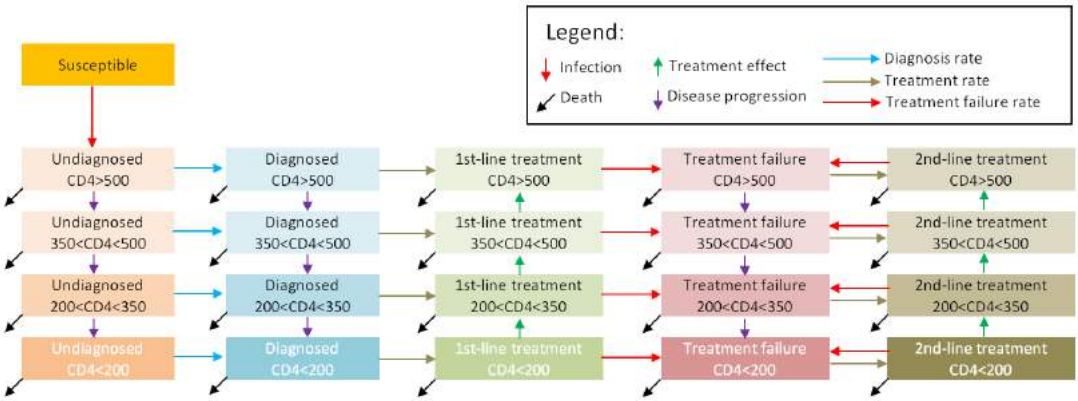
2010) has shown that 20% of MSM report having had sex with women and that 16% are married.

1.5.3. Model of HIV transmission and progression

Optima incorporates a model of HIV transmission and progression. The overall population is partitioned by group and health state. Individuals are assigned to a given population based on their dominant risk; however, to capture important cross-modal types of transmission, relevant behavioural parameters can be set to small but nonzero values.

The model uses a system of ordinary differential equations to track the transmission of HIV and the movement of infected people between 21 health states (**Figure 35**). It distinguishes people who are undiagnosed, diagnosed, and on effective anti-retroviral therapy (ART). Diagnosis of HIV-infected individuals occurs based on a HIV testing rate dependent on CD4 count and population type. Similarly, diagnosed individuals begin treatment at a CD4 count dependent rate. The model tracks those on successful first- or second-line treatment (who have an increasing CD4 count) and those with treatment failure.

Figure 35 Compartments showing HIV infection progression for each population within Optima.



Note: Each box represents a specific disease state or stage with arrows representing the movement of people between states. This structure is repeated for each population modelled.

1.5.4. HIV transmission

HIV infections occur through the interaction between different populations via regular, casual, or commercial sexual partnerships or through sharing of injecting equipment. The rate at which uninfected individuals become infected depends on the number and type of risk events individuals are exposed to in a given period and the infection probability of each event.

For sexual transmission, this rate depends on:

- The number of people in each HIV-infected stage (that is, the prevalence of HIV infection in partner populations)

- The average number of casual, regular, and commercial homosexual and heterosexual partnerships per person
- The average frequency of sexual acts per partnership
- The proportion of these acts in which condoms are used
- The efficacy of condoms
- The extent of male circumcision
- The prevalence of ulcerative STIs (which increase transmission probability)
- The proportion of partners taking ART (we assume effective ART reduces HIV transmission by 70%).

The force of infection incorporates all of these factors and estimates the rate susceptible individuals become infected — which approximately equals the per-capita probability of infection. For sexual transmission from an individual in population g_2 to a susceptible individual in population g_1 at time t and for sexual interaction type i, the force-of-infection is defined as:

$$\lambda(t, g_1, g_2, i) = 1 - \left(1 - \varsigma(t, g_1)\psi(t, g_1)I(t, g_2)\right)^{m(t, g_1, g_2, i)},$$

where λ is the force-of-infection; ς is the effect of circumcision; ψ is the effect of coinfection with other STIs; I is the infectiousness, which is determined by prevalence and transmissibility of individuals in g_2; and m is the number of unprotected acts — as defined in the following paragraphs.

The effect of circumcision is defined as $\varsigma(t, g) = 1 - e_\varsigma p_\varsigma(t, g)$, where e_ς is the fractional reduction in transmission probability per act due to circumcision (i.e., its efficacy), and p_ς is the probability that an individual is circumcised. This probability is zero for female populations and during anal receptive intercourse, so circumcision only protects men during insertive intercourse. The effect of STI infection is $\psi(t, g) = e_\psi p_\psi(t, g)$, where e_ψ is the fractional increase in transmissibility caused by ulcerative STIs (such as HSV-2 and syphilis), and p_ψ is the prevalence of these STIs in population g_2. The infectiousness of a population is:

$$I(t, g) = \sum_h P(t, g, h)\beta(h), \quad (1)$$

where P is the proportion of the infected population in each HIV health state (such that $P(t, g) = \sum_h P(t, g, h)$ is the prevalence of HIV in the population); and $\beta(h)$ is the biological transmission probability, which depends on the viral load (which in turn can be approximated from the individual's CD4 count category h) and on whether the intercourse is insertive, vaginal receptive, or anal receptive.

The number of unprotected acts is $m(t, g_1, g_2, i) = n(t, g_1, g_2, i)\big(1 - e_\kappa p_\kappa(t, g_1)\big)$, where n denotes the number of acts between individuals in two populations, e_κ is the fractional reduction in transmission probability per act due to condom use, and p_κ is the probability of condom use. The effect of condom use appears in the exponent and thereby essentially reducing the number of acts.

The overall force of infection for a given population group g_1 at a given point in time t is the product of all individual forces-of-infection (including injecting interactions, if applicable):

$$\Lambda(t, g_1) = 1 - \prod_{g_2} \prod_{i} \big(1 - \lambda(t, g_1, g_2, i)\big)$$

This quantity is the instantaneous risk at time t of an individual in population g_1 acquiring HIV in Optima. The indices g_2 and i include all sexual and injecting interactions an individual in population g_1 has.

Optima also estimates the number of children infected through mother-to-child transmission using available birth rate data. Breastfed and non-breastfed children are distinguished in the model and children can acquire HIV probabilistically during pregnancy or post-birth via breastfeeding based on empirically observed rates. Optima uses the following equation to calculate the number of infected children born at time t:

$$N_{mtc}(t) = R_b(t)\left[\Big(1 - \epsilon_p p_{bf}(t)\Big)\beta_{bf} + \Big(1 - \epsilon_p\left(1 - p_{bf}(t)\right)\Big)\beta_{nbf}\right] * \sum_w P(t, w)W(t, w)$$

where $R_b(t)$ is the overall birthrate within the female population; $p_{bf}(t)$ is the proportion of females who breastfeed; β_{bf} is the probability of HIV transmission from HIV females who breastfeed to their infants (this includes the probability of transmission during pregnancy and birth); similarly, $p_{bf}(t)$ is the proportion of women who do not breastfeed their children and β_{nbf} is the probability HIV is transmitted to their children during pregnancy and birth; ϵ_p is the efficacy of prevention of mother-to-child transmission (PMTCT); $P(t, w)$ is the prevalence of HIV in adult female population groups w; and $W(t, w)$ is the total number of women in the Zambia population aged between 10 and 49.

1.5.5. HIV infection progression

Once individuals are infected, they can move between the 20 infection-related health states via seven other pathways:

- Individuals may die, either due to the background death rate (which affects all populations equally) or due to HIV/AIDS (which depends on CD4 count and if they are on effective treatment)

- In the absence of treatment, individuals progress from higher to lower CD4 counts
- Individuals can move from undiagnosed to diagnosed states based on their HIV testing rate, which is a function of CD4 count (for example, people with AIDS symptoms have a higher testing rate or may be diagnosed clinically) and population type (for example, FSW usually get tested more frequently than general population females).
- Diagnosed individuals may move onto treatment, at a rate dependent on CD4 count
- Individuals may move from treatment to treatment failure, and
- From treatment failure onto second or higher lines of treatment
- Finally, while on successful first- or second-line treatment, individuals may progress from lower to higher CD4 count

Labelling the four CD4 count categories by h = 1 to 4 (1 = CD4 > 500 cells/µL, 2 = 350 cells/µL < CD4 < 500 cells/µL, 3 = 200 cells/µL < CD4 < 350 cells/µL, and 4 = CD4 < 200 cells/µL) the full set of differential equations describing the movement of people between health states is as follows. The change in the number of susceptible individuals is

$$\frac{dS(t,g)}{dt} = \varepsilon(t,g) - (\Lambda(t,g) + \mu_0)S(t,g),$$

where S is the number of susceptible individuals, ϵ is the entry rate into the population, λ is the force-of-infection (NB: the term λS in this equation equals the incidence for population g at time t), and μ_0 is the background mortality rate. The change in the number of infected but undiagnosed individuals is

$$\frac{dU_{h=1}(t,g)}{dt} = \Lambda(t,g)\, S(t,g) - (\mu_h + \zeta_h(t,g) + \pi_h)U_h(t,g),$$
$$\frac{dU_{h>1}(t,g)}{dt} = \pi_{h-1}U_{h-1}(t,g) - (\mu_h + \zeta_h(t,g) + \pi_h)U_h(t,g),$$

where U_h is the number of undiagnosed individuals in health state h (NB; newly infected individuals ΛS only enter $U_{h=1}$, the CD4>500 compartment), μ_h is the mortality rate for the given health state, ζ_h is the testing rate, and π_h is the disease progression rate ($\pi_{h=4} = 0$, since no progression occurs after CD4<200). The change in the number of diagnosed individuals is

$$\frac{dD_h(t,g)}{dt} = \zeta_h(t,g)U_h(t,g) + \pi_{h-1}D_{h-1}(t,g) - (\mu_h + \tau_h(t,g) + \pi_h)D_h(t,g),$$

where D_h is the number of infected and diagnosed individuals in a particular health state h, and τ_h is the HIV treatment rate. The change in the number of individuals on treatment or with treatment failure is

$$\frac{dA_1(t,g)}{dt} = \sum_h \sigma_h(t,g)D_h(t,g) - (\mu_A + \phi_1)A_1(t,g),$$

$$\frac{dA_2(t,g)}{dt} = \sigma_F(t,g)A_F(t,g) - (\mu_A + \phi_2)A_2(t,g),$$

$$\frac{dA_F(t,g)}{dt} = \phi_1 A_1(t,g) + \phi_2 A_2(t,g) - (\mu_F + \sigma_F(t,g))A_F(t,g),$$

where A_1, A_2, and A_F are the numbers of people on first- and subsequent-lines of ART and treatment failure, respectively; μ_A and μ_F are the mortality rates for individuals on ART and with treatment failure, respectively; and ϕ_1 and ϕ_2 are the failure rates for first- and subsequent-lines of ART, respectively.

In total, the model for has 294 differential equations (14 populations each with 21 health states — as Zambia only uses 12 populations a number of these equations are turned off). Each compartment (**Figure 35**, boxes) corresponds to a single differential equation in the model, and each rate (**Figure 35**, arrows) corresponds to a single term in that equation. Optima solves these equations numerically using a time step of 0.2 years (and effectively converting the differential equations to difference equations).

1.5.6. Optima parameters

Optima divides input parameters into epidemiological, behavioural and clinical parameters. **Table 7** provides a list of model parameter categories. The model uses most of the parameters to calculate the force-of-infection and the impact of interventions.

Table 7 Optima input parameter categories

	Biological parameters	Behavioural parameters	Epidemiological parameters
Population parameters	Background death rate	Proportion of women who breastfeed	Population sizes (TP) Proportion of males circumcised
HIV-related parameters	Sexual HIV transmissibility* (H) STI-related transmissibility increase* Condom efficacy* Circumcision efficacy* HIV health state progression rates (H) HIV-related death rates (H)	Number of sexual partners* (TPS) Number of acts per partner* (S) Condom usage probability* (TP) Circumcision probability* (T)	HIV prevalence (TP) STI prevalence (TP)
MTCT parameters	Mother-to-child transmission probability	Birth rate PMTCT access rate (T)	
Injection-related parameters	Injecting HIV transmissibility* Syringe cleaning efficacy* Drug-related death rate	Number of injections* (T) Syringe sharing probability* (T) Syringe cleaning probability* Methadone treatment probability (T)	
Treatment parameters	ART efficacy* ART failure rates	HIV testing rates (TPH)	Number of people on ART (T)

Notes: T = parameter value changes over time; P = parameter value depends on population group; H = parameter depends on health state; S = parameter depends on sexual partnership type; * = parameter is used to calculate the force-of-infection.

Table 8 Value for each variable parameter in the calibrated model for the Zambia HIV epidemic; values between 2000 and 2020 are smoothly interpolated

Parameter	2000	2020
Population size (000s)		
Female children 0–9 years old	1,572,566	3,447,401
Male children 0–9 years old	1,572,566	3,447,401
Female adolescents 10–19 years old	1,246,462	2,732,511
Male adolescents 10–19 years old	1,246,587	2,732,784
Female youths 20–24 years old	450,864	988,390
Male youths 20–24 years old	450,503	987,599

Parameter	2000	2020
Female adults 25–49 years old	1,293,963	2,836,641
Male adults 25–49 years old	1,293,833	2,836,358
Elderly females > 50 years old	357,618	783,975
Elderly males > 50 years old	357,547	783,818
FSW	30,014	65,797
MSM	4,862	10,659
Population growth (% of overall pop'n/year)	4%	4%
Percentage mothers who breastfeed	99%	99%
Percentage of males circumcised	10.6%	10.6%
Initial HIV Prevalence (% in 2000)		
Female children 0–9 years old	2.8%	
Male children 0–9 years old	2.8%	
Female adolescents 10–19 years old	7.6%	
Male adolescents 10–19 years old	3.5%	
Female youths 20–24 years old	16.3%	
Male youths 20–24 years old	4.8%	
Female adults 25–49 years old	25.2%	
Male adults 25–49 years old	21.6%	
Elderly females > 50 years old	11.7%	
Elderly males > 50 years old	7.0%	
FSW	6.7%	
MSM	3.3%	
STI prevalence (%)		
Female children 0–9 years old	Not sexually active	
Male children 0–9 years old	Not sexually active	
Female adolescents 10–19 years old	2.1%	2.1%
Male adolescents 10–19 years old	0.3%	0.3%
Female youths 20–24 years old	4.4%	4.4%
Male youths 20–24 years old	3.4%	3.4%

Parameter	2000	2020
Female adults 25–49 years old	5.5%	5.5%
Male adults 25–49 years old	7.0%	7.0%
Elderly females > 50 years old	2.5%	2.5%
Elderly males > 50 years old	5.0%	5.0%
FSW	26.0%	26.0%
MSM	19.0%	19.0%
Number of sexual acts: casual (per year)		
Female adolescents 10–19 years old	7.1	7.1
Male adolescents 10–19 years old	7.1	7.1
Female youths 20–24 years old	10.3	10.3
Male youths 20–24 years old	10.3	10.3
Female adults 25–49 years old	10.3	10.3
Male adults 25–49 years old	10.0	10.0
Elderly females > 50 years old	5.0	5.0
Elderly males > 50 years old	5.0	5.0
FSW	9.8	9.8
MSM	12.9	12.9
Number of sexual acts: regular (per year)		
Female adolescents 10–19 years old	70.0	70.0
Male adolescents 10–19 years old	70.0	70.0
Female youths 20–24 years old	100.0	100.0
Male youths 20–24 years old	100.0	100.0
Female adults 25–49 years old	83.2	83.2
Male adults 25–49 years old	83.2	83.2
Elderly females > 50 years old	26.6	26.6
Elderly males > 50 years old	26.6	26.6
FSW	91.1	91.1
MSM	3.7	3.7

Parameter	2000	2020
Number of sexual acts: commercial (per year)		
Male youths 20–24 years old	7.4	7.4
Male adults 25–49 years old	7.4	7.4
Elderly males > 50 years old	7.4	7.4
FSW	395.0	395.0
MSM	15.0	15.0
Condom use: regular (%)		
Female adolescents 10–19 years old	3.4%	3.8%
Male adolescents 10–19 years old	3.4%	3.8%
Female youths 20–24 years old	3.4%	3.8%
Male youths 20–24 years old	3.4%	3.8%
Female adults 25–49 years old	3.1%	3.4%
Male adults 25–49 years old	3.1%	3.4%
Elderly females > 50 years old	3.1%	3.4%
Elderly males > 50 years old	3.1%	3.4%
FSW	11.2%	12.4%
MSM	1.5%	1.7%
Condom use: casual (%)		
Female adolescents 10–19 years old	27.0%	30.1%
Male adolescents 10–19 years old	27.0%	30.1%
Female youths 20–24 years old	27.0%	30.1%
Male youths 20–24 years old	27.0%	30.1%
Female adults 25–49 years old	27.5%	30.6%
Male adults 25–49 years old	27.5%	30.6%
Elderly females > 50 years old	27.5%	30.6%
Elderly males > 50 years old	27.5%	30.6%
FSW	45.4%	49.2%
MSM	28.8%	32.1%

Parameter	2000	2020
Condom use: commercial (%)		
Male youths 20–24 years old	12.4%	14.7%
Male adults 25–49 years old	12.4%	14.7%
Elderly males > 50 years old	12.4%	14.7%
FSW	44.4%	49.3%
MSM	14.1%	16.6%
HIV testing rate (%/year)		
Female children 0–9 years old	Assumed to equal rate pregnant women are diagnosed	
Male children 0–9 years old		
Female adolescents 10–19 years old	4.1%	26.0%
Male adolescents 10–19 years old	1.9%	13.3%
Female youths 20–24 years old	4.1%	26.0%
Male youths 20–24 years old	1.9%	13.3%
Female adults 25–49 years old	4.7%	29.2%
Male adults 25–49 years old	2.8%	18.7%
Elderly females > 50 years old	4.7%	29.2%
Elderly males > 50 years old	2.8%	18.7%
FSW	10.9%	53.1%
MSM	2.9%	19.6%
Clinical diagnosis rate for people with CD4 < 200 cells/µL	98%	98%
Treatment rate for first line ART(%/year)		
For people with CD4 > 500 cells/µL	0%	3.3%
For people with 350< CD4 < 500 cells/µL	0%	21.0%
For people with 200< CD4 < 350 cells/µL	0.1%	74.8%
For people with CD4 < 200 cells/µL	0.3%	90.0%
Treatment rate for second and higher line ART(%/year)	0%	12.4%
Percentage HIV+ pregnant women on PMTCT	5.7%	83.3%

Table 9 Value for each constant parameter in Optima for the Zambia epidemic

HIV transmission	
Per act HIV transmission probability from males to females during sexual intercourse	0.055%
Per act HIV transmission probability from females to males during sexual intercourse	0.1%
Per act HIV transmission probability from males to males during insertive anal intercourse	0.06%
Per act HIV transmission probability from males to males during receptive anal intercourse	0.5%
Probability of mother-to-child transmission through breastfeeding	35%
Probability of mother-to-child transmission if breastfeeding is excluded	22.5%
Multiplicative change in transmission probability when partner has CD4 > 500 cells/µL	1.6
Multiplicative change in transmission probability when partner has CD4 < 200 cells/µL	3.8
Reduction in transmissibility when HIV+ partner is on effective treatment	70%
Efficacy of condoms	95%
Efficacy of circumcision	60%
Multiplicative change in transmission probability after diagnosis	0.75 (25% reduction)
Multiplicative change in transmission probability due to presence of other ulcerating sexually transmitted infections	2
Efficacy of syringe cleaning	75%
Efficacy of OST	95%
Efficacy of PMTCT	95%
Multiplicative change in transmission probability due to treatment risk compensation	1.1
Infection progression and mortality	
Infection progression rate from CD4 > 500	24.5% per year

HIV transmission	
cells/µL to 350 < CD4 < 500 cells/µL	
Infection progression rate from 350 < CD4 < 500 cells/µL to 200 < CD4 < 350 cells/µL	51% per year
Infection progression rate from 200 < CD4 < 350 cells/µL to CD4 < 200 cells/µL	51% per year
Treatment recovery rate from CD4 < 200 cells/µL to 200 < CD4 < 350 cells/µL	45% per year
Treatment recovery rate from 200 < CD4 < 350 cells/µL to 350 < CD4 < 500 cells/µL	70% per year
Treatment recovery rate from 350 < CD4 < 500 cells/µL to CD4 > 500 cells/µL	36% per year
Death rate for HIV+ people with CD4 > 500 cells/µL	Background + 0.052% per year
Death rate for HIV+ people with 350 < CD4 < 500 cells/µL	Background + 0.12% per year
Death rate for HIV+ people with 200 < CD4 < 350 cells/µL	Background + 1.1% per year
Death rate for untreated HIV+ people CD4 < 200 cells/µL	Background + 22.8% per year
Death rate for HIV+ people with CD4 < 200 cells/µL on treatment	Background + 4% per year
Treatment failure rate for first-line ART	7.5% per year
Treatment failure rate for second-line ART	7.5% per year

1.6. Model Calibration

We calibrated Optima to Zambia's HIV epidemic to match available population group HIV prevalence data and the number of people taking ART from 2000–13. While primarily calibrated to match epidemiological data, Optima calibrates each input parameter to match available demographic, behavioural, biological and clinical data for Zambia. Given the challenges inherent in quantifying all known constraints on an epidemic, we calibrated the model manually, with oversight by with in-country stakeholders where possible. The values of each parameter in 2013 represent current conditions for each simulation.

1.6.1. Reconciliation with cost-outcome relationships

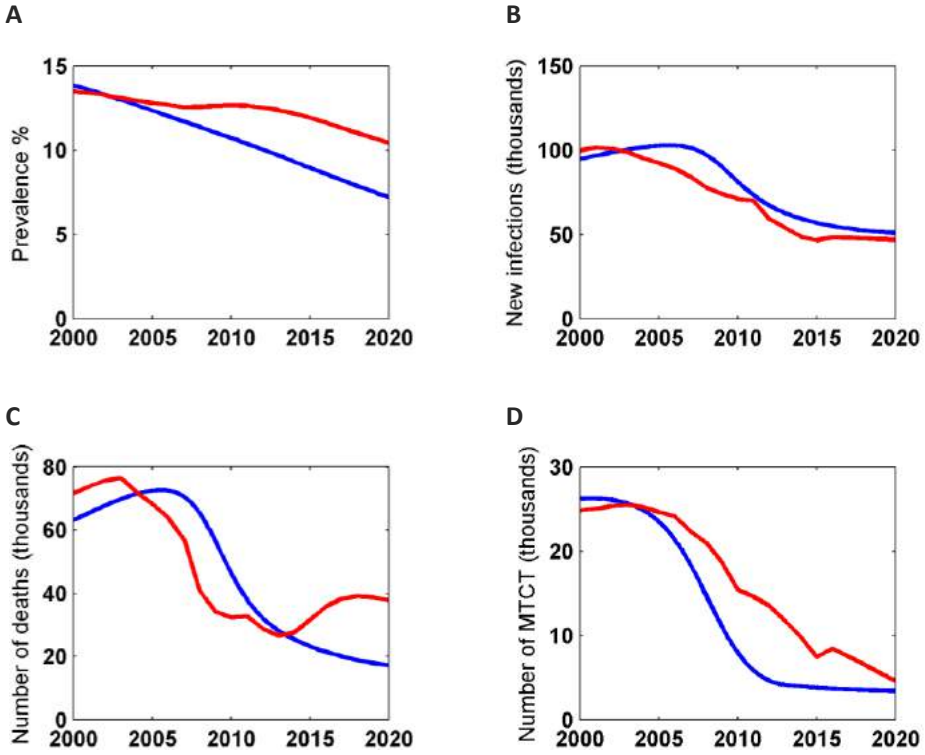
The parameter values for the best-fit simulation in 2013 need to match the outcome values corresponding to the estimated 2013 spending levels in the cost-outcome relationships (described in detail below). Otherwise, there will be a mismatch in parameter values for future

projections and a sharp change in epidemiological trends even if there is no change in spending. We adjusted the calibration to match the data used in the logistic cost-outcome relationships.

1.6.2. Comparison with Spectrum outputs

During the calibration process, we also calibrated the model to align with the epidemic trends in prevalence, overall incidence, mother-to-child infections, and HIV/AIDS deaths obtained from Spectrum (**Figure 36**).

Figure 36 Comparison between Optima and Spectrum outputs



Note: In each figure Optima results are in blue and Spectrum outputs are in red. (A) HIV prevalence in Optima for people 10 years and from Spectrum for people 15 years and older. (B) Annual HIV incidence in Optima for people 10 years and from Spectrum for people 15 years and older. (C) Annual number of AIDS deaths in the overall population. (D) Number of mother-to-child transmissions.

The epidemiological trends projected by Spectrum and Optima generally align over 2000–20. However, in comparison to Spectrum estimates, Optima projects a faster decline in prevalence and shows a later peak in new infections and AIDS deaths.

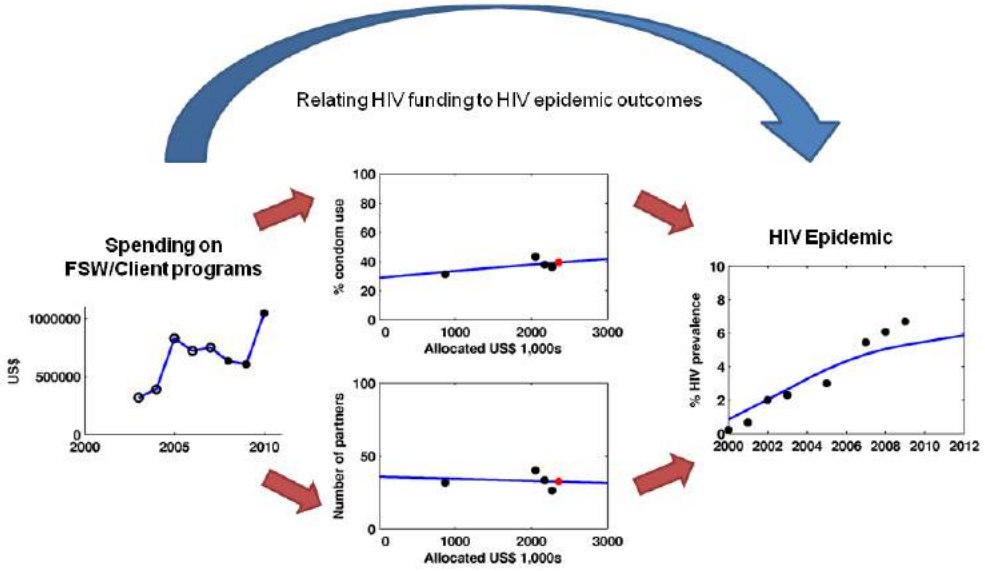
1.7. Impact of Programme Funding and Cost-outcome Relationships

A central component of our analyses is the relationships between the cost of HIV prevention programmes and the resulting outcomes for each population and prevention programme within Zambia. Such relationships are required in our analyses, to understand how incremental changes in spending ultimately affect HIV epidemics and determine the optimal funding

allocation. In our analysis, we used logistic/sigmoid functions to describe the relationships between an outcome of a programme (such as a change in coverage, condom use, or number on ART) and the total cost for implementing the programme. We fit these cost-outcome curves to available data as best as possible. The supplementary file Zambia_cost-outcome_curves.xlsx contains all data used to inform these relationships. Using these relationships, any change in HIV programme funding directly affects risk behaviours and changes the HIV epidemic.

We used an ecological "top-down" approach to relate programme cost and outcomes. For each key population and programme, we derived a set of relationships directly linking estimated funding to behavioural data for the population's primary risk-behaviour (see schematic in **Figure 37**). We describe our approach in detail below. To produce these relationships we assume indirect costs have no direct impact on HIV transmission parameters. A limitation of our approach is the assumption that all changes in behaviour are assumed to be due to changes in programme funding.

Figure 37 Example of the relationship between spending on FSW/client programmes and the HIV epidemic (numerical values are for illustrative purposes only)



1.7.1. Cost-outcome relationship methodology

We use a logistic or sigmoid function to model cost-outcome relationships. This type of function can incorporate initial start-up costs, which may have no direct effect on a behavioural outcome, and allow changes in behaviour to saturate at high spending levels. **Table 10** and section 4.3 present information on the cost-outcome relationships we considered for Zambia, and the cost-outcome curves established. Using our data synthesis, we identified years where both spending data and outcome data for each model population. We then used this data to fit a four parameter logistic function of the form

$$L(x) = A + \frac{B-A}{1+e^{-D(x-C)}},$$

where $L(x)$ relates spending to outcome, x is the estimated amount of funding for the programme, A is the lower asymptote value (adjusted to match the value of *L* when there is no spending on a programme), B is the upper asymptote value (for very high spending), *C* is the midpoint, and D is the steepness of the transition from A to B. Our fits were further constrained using an assumed range for the maximum/saturation value of the outcome.

We fitted the logistic function to the available data and saturation range using Matlab© 2012b with a trust region reflective algorithm [12]. We then adjusted each fit to reflect assumed zero spending values and expected changes in outcomes with increases in spending—with further adjustments to remove unrealistic trends, to reconcile with calibrated outcome values, and in response to feedback from in-country stakeholders.

1.7.2. Zambia cost-outcome relationships and assumptions

Table 10 Assumed zero spending and saturation values for each cost-outcome relationship

Program	Behavioural or clinical outcome affected	Assumed Zero spending value	Assumed Saturation Value
General population BCC and condom programmes	Casual condom use in youths: proportion of casual acts protected	19.7%	60%
	Casual condom use in adults: proportion of casual acts protected	26.1%	60%
	Regular condom use in youths: proportion of regular acts protected	1.2%	20%
	Regular condom use in adults: proportion of regular acts protected	2.1%	30%
FSW and client programmes	Commercial condom use: proportion of commercial acts protected	49%	95%
	Casual condom use FSW: proportion of casual acts protected	32.4%	95%
	Regular condom use FSW: proportion of regular acts protected	1.4%	40%
Voluntary medical male circumcision programmes	Overall number of males aged 0–49 years circumcised each year	0	NA—Based on an average unit cost of

Program	Behavioural or clinical outcome affected	Assumed Zero spending value	Assumed Saturation Value
			US$86.25 per circumcision
MSM programmes	Casual condom use: proportion of casual acts protected	33.7%	70%
	Regular condom use: proportion of regular acts protected	2.0%	40%
Prevention of mother-to-child transmission (PMTCT)	Proportion of HIV+ pregnant women who are on PMTCT	0%	98%
HIV counselling and testing (HCT)	HIV testing: proportion of general population female youths tested	0%	60%
	HIV testing: proportion of general population male youths tested	0%	50%
	HIV testing: proportion of general population female adults tested	0%	60%
	HIV testing: proportion of general population male adults tested	0%	50%
	HIV testing: proportion of FSWs tested	0%	90%
	HIV testing: proportion of MSM and transgender tested	0%	70%
Anti-retroviral therapy (ART)	Overall number of people on taking anti-retroviral therapy (first-line, second-line, and those experiencing treatment failure)	0%	NA—Based on an average unit cost of US$280 per year

1.7.3. Modelling the impact of voluntary medical male circumcision

Optima models the impact of voluntary medical male circumcision (VMMC) by updating the proportion of males circumcised in the overall population. We assume circumcision only prevents the acquisition of HIV and there is no direct reduction in transmission from positive circumcised men to their partners. Based on this assumption, we also assume only susceptible males undergo VMMC in the model. For a given level of spending allocated to VMMC and the associated unit cost, Optima calculates the overall number of males that can be circumcised each time step — with the number of circumcisions occurring in each population prioritised for

VMMC is in proportion to population size. For this analysis of the Zambia HIV epidemic, we assumed a maximum VMMC coverage of 80% for males aged less than 50 years. The model then updates the current proportion of males circumcised in each male population (taking into account deaths, population movement, and new circumcisions at birth during the current time step).

1.8. Optimal Allocation Methodology

The primary aim for our analysis is to determine the allocation of resources or spending required that best meet specific objectives. This 'optimal' allocation of funding to all HIV programmes for a fixed budget depends on the objective specified. We used Optima with the best-fitting simulation and an optimisation method to find the optimal allocation of resources best achieving these objectives for a specific budget amount. This optimisation process essentially searches through the space of programme spending (using an adaptive stochastic linear gradient-descent optimisation method) to find the allocation that minimises the difference between the current outcomes and the desired outcomes. Formally, the optimisation finds:

$$min\left(\sum_{objectives} \max\left(O_c, O_d\right)\right)$$

where O_c is the value of an objective (e.g. projected number of in HIV/AIDS deaths over 2014–30) for the current HIV/AIDS programme allocation and O_d is the desired value for the objective (e.g. number of HIV/AIDS deaths over 2014–30 corresponding to a 29% reduction).

Figure 38 illustrates our optimisation approach. To initiate the optimisation process for a specified funding level, a random allocation is used. We ensured Optima found the global minimum by running the optimisation multiple times.

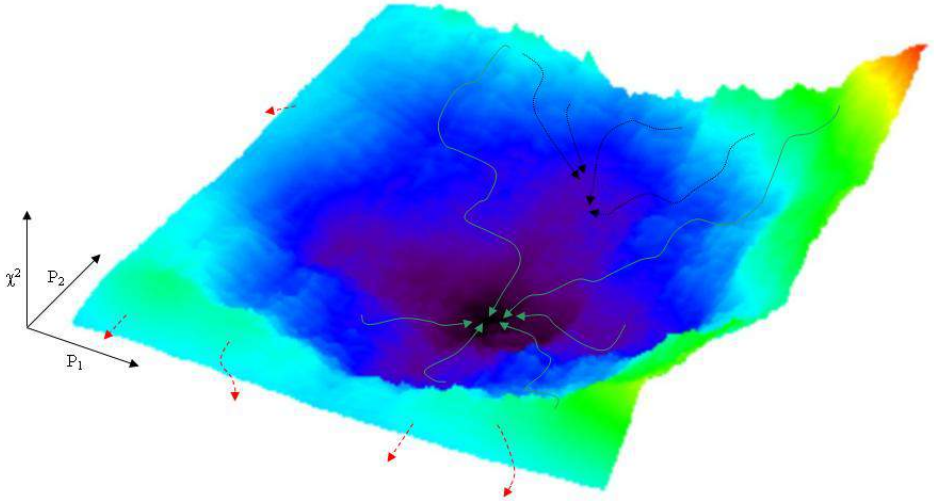
To calculate the value of each objective in the future for a specific programme allocation in 2013, Optima calculates the values of each spending outcome using the cost-outcome relationships and then simulates the resulting HIV epidemic over 2014–30. For these projections, we assumed spending on each prevention programme remains constant at the 2014 level. This means for ART the number of people on treatment remains constant and for VMMC the number of people who can be circumcised each year is constant.

Based on this optimisation methodology, Optima can also calculate the required minimal spending to satisfy multiple objectives using the following steps:

1. Start with a small fixed budget in 2014
2. For this fixed budget, Optima randomly allocate funding to prevention and ART programmes. Using its optimisation algorithm, Optima then adjusts the allocation, effectively searching through programme spending parameter space, until the resulting allocation most closely meets the specified objectives.
3. If the desired objectives are not met, Optima then increases total spending incrementally, repeating step 2), until all objectives are satisfied and the optimisation process stops.

To estimate the total spending required, we assume indirect costs scale in the same proportion as for the 2012 spending. Overall spending then equals the sum of the minimal spending for prevention and ART programmes and the corresponding indirect costs.

Figure 38 Schematic of the programme allocation "landscape"



Note: The two horizontal axes represent the spending allocated to two programmes. The vertical axis represents the outcome obtained from the model for each spending allocation. Depending on the objective, our method will start from a random allocation and find the point where the outcome is a global minimum or global maximum. The red line shows the path taken by the gradient descent method to find the allocation minimising the outcome.

1.9. Future Commitments Calculations

To calculate the future costs of providing healthcare and treatment to PLHIV for a specific scenario, we ran optima for the specified period and determined the number of diagnosed PLHIV and number of people on first-line ART, on second-line ART, and experiencing treatment failure for each CD4 count category at each time step. Optima then calculated the total cost by multiplying the number of people in each infection category by the corresponding unit cost. For

this calculation, we assumed all those experiencing treatment failure are taking first line treatment. When necessary, we used an annual discount rate of 3%.