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Cross-sectoral co-financing: Taking a multi-payer perspective in the financing and economic evaluation of structural HIV interventions

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ABSTRACT

Background: Global HIV resource needs estimates are ever-increasing. There is growing interest in creating domestic fiscal space and prioritising the most cost-effective interventions. Concurrently, structural drivers and barriers are undermining the efficiency of HIV programmes to deliver on ambitious treatment and prevention targets. Yet, limited HIV resources are being channelled to interventions addressing these upstream factors. Conventional priority-setting and financing frameworks that only consider HIV outcomes and budgets, are further hampering investments in structural interventions that tend to be implemented in other sectors, for other objectives. Opportunities to factor in synergies with non-HIV investments tend to be missed, due to a lack of data on their multiple outcomes; the dominance of single outcome economic evaluation frameworks; and weak incentives for joint financing between sectors. The aim of this thesis is to develop and explore the application of a novel methodological approach for both fiscal space analysis and economic evaluation that considers multiple intervention benefits and multi-sectoral payers.

Methods: The research uses a mixed methods approach, including case studies, econometric analysis, economic evaluation, and qualitative interviews, with data from selected countries in sub-Saharan Africa.

Results: A 'co-financing' approach is developed for factoring non-HIV benefits and payers in HIV resource allocation. It is compared to other economic evaluation approaches, and to a unisectoral conceptualisation of cost-effectiveness thresholds. This approach is then used to explore the potential for creating fiscal space for HIV through co-financing of health system and broader development investments. Co-financing is also applied to the economic evaluation of a food support intervention for people initiating antiretroviral therapy. Finally, the institutional feasibility of adopting a co-financing framework in real-world HIV resource allocation is investigated from the perspective of policy-makers in Tanzania.

Conclusion: Co-financing across sectors and budgets could optimise resource allocation and prevent welfare loss, but it will require strong cross-sectoral coordination and institutional incentives.

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ABBREVIATIONS AND ACRONYMS

AIDS	Acquired Immunodeficiency Syndrome
ANC	Antenatal Care
ART	Antiretroviral Treatment
ARV	Antiretroviral Drug
BCR	Benefit-Cost Ratio
CBA	Cost-Benefit Analysis
CCA	Cost-Consequence Analysis
CCM	Country Coordinating Mechanism
CD4	Cluster of differentiation four
CEA	Cost-Effectiveness Analysis
CER	Cost-Effectiveness Ratio
CI	Confidence Interval
DAC-CRS	Development Aid Committee
CUA	Cost-Utility Analysis
DALY	Disability-Adjusted Life Year
GDP	Gross Domestic Product
GFATM	Global Fund to Fight AIDS, Tuberculosis and Malaria
HiAP	Health in All Policies
HIV	Human Immunodeficiency Virus
HSV-2	Herpes Simplex Virus type 2
ICER	Incremental Cost-Effectiveness Ratio
IEC	Information-Education-Communication
IMAGE	Intervention with Microfinance for AIDS and Gender Equity
IMF	International Monetary Fund

IPV	Intimate Partner Violence
LMIC	Low and Middle-Income Country
LTFU	Loss to Follow Up
MAP	Multi-sectoral AIDS Programme
MDG	Millennium Development Goal
NAC	Nutrition Assessment and Counselling
NGO	Non-Governmental Organisation
NICE	National Institute for Health and Care Excellence
OECD	Organisation for Economic Cooperation and Development
OLS	Ordinary Least Squares
PEPFAR	President's Emergency Plan for AIDS Relief
PLHIV	Person Living with HIV
PMTCT	Prevention of Mother-to-Child Transmission
UMIC	Upper-Middle Income Country
UNAIDS	Joint United Nations Programme for AIDS
UNDP	United Nations Development Programme
QALY	Quality-Adjusted Life Year
RR	Risk Ratio
SDG	Sustainable Development Goal
SSA	Sub-Saharan Africa
STI	Sexually Transmitted Infection
UK	United Kingdom
US	United States
USD	United States Dollar
WHO	World Health Organisation
WTP	Willingness-To-Pay

CHAPTER 1 INTRODUCTION

1.1 Rationale of the thesis

In two decades, the HIV epidemic evolved from the 33rd cause of global mortality and morbidity in 1990 to the fifth cause in 2010 (1). According to UNAIDS, AIDS has claimed 35 million lives, orphaned over 17 million children and left 36.7 million people living with HIV (PLHIV) who will depend on treatment and care to survive (2-4). The situation is particularly dire in sub-Saharan Africa (SSA), where 27.5 million people live with the virus, of which 58% are women (4, 5). In 2015, an estimated 1.4 million Africans were newly infected and 800,000 died of AIDS-related causes (4). Until recently, the epidemic had reversed hard-won gains in life expectancy in the region and also had serious negative economic consequences for affected households (6, 7).

Since the turn of the century, the global and regional AIDS responses have been dramatically stepped up, with the advent of effective treatment and intensive global advocacy for equitable and affordable access to HIV services (3). The past fifteen years witnessed an unprecedented increase in spending on HIV, with global investments in the response in low and middle-income countries (LMICs) multiplying more than six-fold, to about USD 19.1 billion in 2016 (7, 8). An exceptional and urgent response called for an exceptional investment, as exemplified by the creation of the Global Fund to Fight AIDS, Tuberculosis and Malaria (GFATM) and the US President's Emergency Plan for AIDS Relief (PEPFAR). Starting from about 300,000 people on antiretroviral therapy (ART) in LMICs in 2002, a remarkable 18.2 million were receiving lifesaving treatment by mid-2016 and 1.4 million infections among infants had been prevented (4, 7).

Nonetheless, the need continues to outpace the response, with over 18 million PLHIV still not receiving treatment, including 70% of children living with HIV; 25% of HIV-positive pregnant women in priority African countries not receiving antiretroviral drugs that could eliminate vertical transmission; and about 50% of male circumcisions performed of those needed to achieve a public health impact in high-burden countries (5, 7). Despite the promise of universal treatment and biomedical prevention, the number of new HIV infections remains high, and only 44% of all PLHIV are currently virally suppressed (7, 9). Clearly, too many people at risk of and living with HIV are being lost at various points along the prevention and treatment cascades (10, 11). There is growing recognition of the critical role of structural drivers in shaping the environment in which HIV risk occurs, and in constraining the uptake of and adherence to HIV prevention and treatment services (10). These structural factors and barriers are impeding the effectiveness of HIV programmes and their ability to meet the ambitious global goal of ending AIDS as a public health threat by 2030 (9).

Indeed, there is compelling evidence to suggest that HIV risk and service uptake are associated with low levels of schooling, poverty, food insecurity, gender-based violence, problematic alcohol use, and stigma. For one, education has been increasingly emerging as a protective factor and social vaccine for HIV, especially for adolescents and young girls (12-16). Although the relationship with wealth is more mixed (17, 18), food poverty and insecurity also appears to be linked to risky sexual behaviours among women, and ART non-adherence (19-25). Stigma has been a persistent barrier to the use of HIV prevention tools, and continues to hamper HIV testing, linkage and retention in care, while evidence on problematic alcohol use reports negative associations with treatment outcomes (26-29). Gender inequality and gender-based violence consistently come out as key underlying drivers of HIV that further reinforce the negative effects of poverty, poor education and access to basic services (30-34).

As has been found with the broader social determinants of health, investments in other non-health sectors that address these structural barriers and drivers may therefore be good HIV investments (35-39). The evidence base on the effectiveness of structural interventions for HIV has been growing in recent years, and although few have been rigorously evaluated, there are several promising models (40-51). Conditional cash transfers to keep girls in school, or educational reforms that increase secondary schooling, have been found to have a significant and sizeable impact on HIV risk in Malawi, Botswana and Uganda (40, 52-54). There is some evidence that economic empowerment interventions for women, such as microfinance loans, could decrease risky sexual behaviours and increase HIV service uptake (42, 55, 56). Group sessions and community-based models to transform gender norms have reduced intimate partner violence and HIV-related risk behaviour among men (48, 49). Social protection programmes and in-kind support that address poor livelihoods, malnutrition and food insecurity can improve effective ART coverage and levels of viral suppression (22, 57-60). Other fiscal interventions, such as alcohol taxation, may generate revenues while impacting on HIV at the same time (61).

However, despite the growing evidence of the important role of structural factors in driving HIV transmission and constraining service scale-up, very limited HIV resources are being channelled to effective interventions addressing these issues (62-65). Some even argue that there has been an overemphasis on the need for a multi-sectoral response for HIV that has hampered a more prioritised approach, focused on cost-effective interventions with HIV endpoints (65, 66). In this discourse, structural interventions that address distal determinants of HIV risk and service use, are unlikely to compare favourably to interventions tackling more proximal determinants, if only valued for their HIV outcomes. Indeed, when HIV budgets are being optimised, the focus is usually on maximising HIV impact, which implies that non-HIV outcomes are largely ignored and interventions with multi-sectoral benefits thereby undervalued and under-prioritised (67, 68). Besides the limited availability of trial data on the effectiveness of such interventions for HIV, it is likely that these

prevailing priority-setting frameworks are further hampering investments in structural interventions, despite their likely HIV pay-offs (69, 70).

Indeed, standard economic evaluation methods that are used tend to be confined to the 'HIV-only' domain. For example, increased secondary schooling or a cash transfer to keep girls in school would appear expensive and not good value-for-HIV-money, if their education benefits were not factored into the financing decision (52, 53). The same is true for public health interventions with multi-sectoral impacts and health system strengthening interventions with multiple disease impacts (71-73).This reflects a lack of adequate economic analysis methods to evaluate the value for money of such upstream interventions.

Moreover, this is compounded by an inadequate financing framework that does not consider non-HIV programmes when estimating the HIV resource envelope. The interpretation of a multi-sectoral HIV response has been quite narrow and largely defined in practice as implementing traditional HIV interventions (such as condom distribution, behaviour change, treatment and care) in non-health sectors (74). Interventions with non-HIV primary objectives are not generally considered to merit HIV resources (65), therefore current approaches do not look beyond the traditional HIV budget, and overlook potential financing from cross-sectoral synergies.

One of the approaches used to estimate resource envelopes and assess the extent to which it is desirable for countries to fund HIV, without damaging other developmental or economic objectives, is to apply the concept of fiscal space. Fiscal space is defined as the additional budgetary room available to invest in a specific objective without compromising fiscal sustainability (75). The potential sources of fiscal space naturally vary from country to country, given their different economic fundamentals and governance structures (76, 77). To date, fiscal space analyses have been conducted for health in general (78-81) and for HIV in particular (82-85). These studies have tended to be narrow in their definition of what can be considered expenditures to achieve health or HIV objectives, thereby ignoring a range of investments that could be leveraged beyond the traditional sector or vertical programme boundaries (75, 86). Moreover, existing analyses have underestimated (or discarded) other non-financial resource constraints and limitations in absorptive capacity, which seriously hamper effective fiscal space (87, 88). Yet, if the HIV response does not consider broader development finance aims, then creating more fiscal space for HIV-specific interventions may crowd out investments in these other areas (89).

This is of concern, since such interventions represent an opportunity to capitalise on existing non-HIV investments. They also come with clear incentives for Ministries of Finance, as they generate 'multiple bangs for the same buck', and minimise the risk associated with the uncertainty surrounding intervention impact (90). Similarly, opportunities are arguably being missed to invest in structural health system strengthening, rather than short-term solutions to structural constraints (36, 51, 91-107). This could lead to a zero-sum game where resources allocated to interventions

with non-HIV primary objectives are effectively foregone HIV resources, thereby creating inefficiencies by hampering synergistic investments.

Given the current financing landscape and the growing costs of the HV response, efficiencies are acutely needed. Indeed, the resource need estimates of responding to the epidemic have been mounting with the roll-out of treatment and the growing arsenal of HIV interventions (67). In its Fast Track strategy launched in 2014, UNAIDS underlined the imperative of frontloading investments to control the epidemic by 2020, at the risk of seeing incidence and costs rise thereafter (68, 108). Its estimates of global resources needed in 2020 range between USD 26 and USD 32 billion (67, 108-110), which is around one-fifth of the USD 143 billion disbursed by OECD countries in 2016 as official development assistance (111). South Africa's new national plan for HIV/Tuberculosis/STIs alone has been costed at USD16 billion (2017-2022) (112). The cost to meet the need outstrips the domestic resources available to many countries and is likely to keep increasing, especially in countries where the 'tipping point' or 'AIDS transition' has not yet been met – i.e. the number of new infections continues to outweigh the number newly initiated on ART (113).

An analysis by the World Bank likened the commitments to implementing national HIV strategic plans to fiscal quasi-liabilities that would indebt governments to continue providing services – akin to the European pension debt (114). These estimated fiscal 'quasi-liabilities' incurred by HIV programmes until 2030 ranged from a non-negligible 37% of GDP in South Africa to a striking 293% of GDP in Swaziland (115). Given this so-called 'treatment mortgage', it is becoming increasingly evident that more effective prevention is needed to ensure that future treatment can be sustained (113). This would also minimise the risk to affected countries of crippling their economies by crowding out other meritorious public investments due to accumulated entitlements (89, 94, 115, 116). Indeed, most of these quasi-liabilities are attributable to treatment costs, which are relatively 'harder' commitments to keeping people alive, that risk squeezing out the more discretionary-type investments in prevention, which are already remarkably low in most affected countries (as low as 10%) (110, 117, 118).

To date, the funding gap in much of SSA has been largely filled by external funds from bilateral and multilateral donors, which have accounted for 27% to 98% of national HIV spending (115, 118), and have partially substituting out-of-pocket expenditures (97, 119). However, development assistance for health and for HIV has flat-lined over the past 5 years (120, 121) and 'HIV fatigue' is reducing the policy space available at the donor level to single out HIV programmes (83, 89, 94, 122-124). A key future source of financing will have to be HIV-affected countries themselves (125, 126), many of which have been experiencing robust economic growth (127). These countries are now expected to take on their 'shared responsibility' and shoulder more and more of the growing costs of ART for current and future PLHIV, as well as continue to invest in prevention (128). The latest estimates suggest that domestic HIV financing increased steadily from USD 2.1 billion in

2000 to USD 6.6 billion in 2012, of which a large share was spent by African governments (47%) (5, 125, 129). Yet, for low-income and lower middle-income countries, it will remain extremely difficult to take on this fiscal burden from domestic sources alone in the near future (129).

At the same time, the international community has embraced a new development agenda with 17 Sustainable Development Goals (SDGs), of which only one is focussed on health (130, 131) – in stark contrast to the Millennium Development Goals (MDGs) where 3 of the 8 goals were health-related. Governments have a growing set of priorities that are competing for scarce resources, including climate change mitigation, food production, infrastructure development, education, gender equality, and multiple communicable and non-communicable disease burdens, among many others. In this context, it will be increasingly challenging to make the case for increased HIV-specific public resources going forward, especially given the perception that the HIV response has been over-funded and received a disproportionate share of total health expenditures (132-135). However, greater investments in other health and development areas do not necessarily mean disinvestment in HIV objectives, but they do make it all the more important to leverage these non-HIV investments. There may also be scope to optimise specific complementarities between existing health or development programmes for HIV impact (136). For example, while microfinance alone may have an unclear effect on HIV-related risk behaviour and service utilisation, combining microfinance with a gender and HIV training component could enable the realisation of its HIV potential (44-46).

To overcome the sub-optimal investments in these types of interventions and recognise their mutual benefits across sectors and budgetary authorities, some high-income countries have experimented with joint budgeting or co-financing models. These have involved pooling health and social care budgets, with mixed results and significant institutional challenges (137, 138).

While such investments and their associated economic arguments are particularly potent, opportunities for co-investments tend to be missed due, among others reasons, to a lack of data on their multiple benefits and value for money from a societal perspective; the dominance of single outcome cost-effectiveness frameworks used in health economic evaluation; and weak mechanisms for co-financing between sectors and health programmes, as prevailing institutional and budgeting arrangements disincentivise cross-sectoral arithmetic (53, 139, 140). Methodological developments are therefore required to fully assess the economic value of structural interventions and the available fiscal space for HIV in a way that considers the interactions between sectors and the creation (or restriction) of fiscal space through health systems and broader development investments. Moreover, a better understanding of the institutional incentives that may support or hamper intra-sectoral and cross-sectoral investments could inform policy recommendations to address these potential inefficiencies.

1.2 Research aim and objectives

The aim of this thesis was to develop and explore the application of a novel methodological approach for both economic evaluation and fiscal space analysis that considers multiple intervention benefits and multi-sectoral payers, in the context of HIV.

To achieve this aim, the study sought to meet the following specific objectives:

1. To develop a methodological approach – 'co-financing' – for factoring in non-HIV benefits and non-HIV payers in the decision rules of resource allocation;
2. To explore the potential of creating fiscal space for HIV across sub-Saharan Africa, incorporating the value of co-financing in health system strengthening and broader development investments;
3. To apply the co-financing approach by assessing the benefits and potential of co-financing of a food support intervention in various country settings;
4. To understand in practice the institutional barriers, enablers and (dis)incentives to adopting a co-financing framework in HIV financing and priority-setting.

1.3 Structure of the thesis

The thesis starts with a general literature review, followed by a description of the overall study design and methods. Next, there are five results chapters, and a final discussion. Each of the results chapters follow a paper-style format, with their own methods and discussion sections. Some also have more detailed technical appendices, which can be found at the end of the thesis.

The next chapter presents an overview of the literature on public resource allocation across sectors, fiscal space and economic evaluation of interventions with multi-sectoral outcomes, as well as the literature around inter-sectoral governance, joint budgeting and co-financing models for upstream programmes. This chapter seeks to frame the study in the context of the most relevant strands of literature and highlight the existing gaps. Chapter 3 goes on to describe the study design and justification for the choice of mixed methods adopted for each objective.

Chapter 4 is a methodological paper in which a novel co-financing approach is proposed and supported with an empirical example of a case study from Malawi. In Chapter 5, the approach is further developed in terms of conceptualising cost-effectiveness thresholds from a multi-sectoral perspective, using a stylised two-sector model for health and education.

Chapter 6 reports on an adapted fiscal space analysis for HIV in 14 sub-Saharan African countries that incorporates co-financing as a potential source of fiscal space and explores the implications of effective non-HIV investments for the HIV resource envelope.

Chapter 7 presents an application of co-financing as an analytical technique in economic evaluation. It assesses the economic returns of a food assistance intervention for people initiating ART in 5 different country settings in sub-Saharan Africa, based on its HIV and food security impacts.

Chapter 8 explores the institutional feasibility of a co-financing model and mechanism, and seeks to identify the enablers and barriers to the adoption of this potentially efficiency-enhancing approach through a series of in-depth interviews with decision-makers in Tanzania at the national level.

Finally, Chapter 9 summarises the main findings of the thesis, and reflects on its limitations and key contributions to the literature. It also identifies policy implications and proposes avenues for future research.

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CHAPTER 2 LITERATURE REVIEW

The aim of the literature review was to identify and appraise the methods for assessing and leveraging financing for structural HIV interventions, with a particular focus on broader health and development resources and efficiency gains from cross-sectoral synergies.

There are two distinct steps in the allocation of public resources that this thesis was particularly interested in. The first is the allocation of the total public budget to various sectors of the economy and of government, and the second is the allocation of those government sector budgets to specific interventions. The literature review therefore starts with the concept of fiscal space, as an approach to estimate the resource envelope, and its applications for HIV and health. This is followed by a review of methods to guide sectoral resource allocation processes and financing decisions, with a focus on health. Finally, the review considers the evidence of real-world experiences with institutional arrangements that encourage cross-sectoral financing, including their feasibility and performance.

Based on the rationale and objectives of this thesis, three separate reviews were conducted to answer the following questions:

- What are the methods used to estimate the resource envelope or fiscal space for HIV or health, and to what extent do they build in health-producing investments in other sectors?
- What are the available methods to economically evaluate interventions with multiple benefits across sectors/payers, and are they being applied in health?
- What are current approaches to govern and finance programmes requiring cross-sectoral coordination and investments?

For each area, the review consisted of a combined approach with a review of key reference texts or existing reviews on the topic; and an online literature search of selected electronic databases, and relevant authoritative websites. Both peer-reviewed and grey literature were considered to minimise publication bias. The bibliographies of identified publications were screened and experts were consulted to ensure that no key studies or texts had been omitted. Details on the search terms and inclusion/exclusion criteria of each search are described below.

This chapter is structured along the lines of the three reviews, starting with a summary of the literature on estimating fiscal space and HIV financing; followed by the methods for the economic evaluation of interventions with multi-sectoral benefits; and the institutional and financing responses to coordinate and implement such health-related interventions. The chapter ends with a summary of the three bodies of literature and key gaps that this study sought to contribute to.

2.1 Resource Envelope and Fiscal Space

For the search related to existing methods for the estimation of the HIV resource envelope, three electronic databases were searched (Pubmed, Econlit, GoogleScholar) with terms related to 'HIV', 'AIDS' or 'health'; and 'fiscal space', 'financing', 'funding', 'spending', or 'expenditures' in the title. In addition, websites of the following organisations were screened: the International Monetary Fund (IMF), World Health Organization (WHO), World Bank, Organisation for Economic Cooperation and Development (OECD), UNAIDS, Overseas Development Institute, Kaiser Family Foundation, as well as abstracts from the International AIDS Conferences and the International AIDS Economics Network conferences. There was no geographic, publication date or language restriction, but the search was conducted in English. Publications were retained if they presented or applied methods to prospectively or retrospectively estimate the fiscal space or funding availability for HIV programmes in particular, or health in general.

The following key frameworks and approaches were identified: Heller's work on fiscal space for health in LMICs (1, 2); the World Bank's framework and publications on fiscal space for health and HIV (3, 4); and the WHO's background papers for the 2010 World Health Report on health systems financing (5, 6). Through further bibliographic searches, selected resources on estimating general fiscal space were also consulted to provide a broader framing and explore how cross-sectoral spill overs were taken into account. These included publications by the IMF and the United Nations Development Programme (UNDP) in the context of the Millennium Development Goals (MDGs) scale-up (7, 8). Although there is a case to be made against sector-specific analyses of public financing sources, precisely because of the interactions across sectors and the need for flexible fiscal policies, the reality is that the current HIV and health financing architecture in LMICs is characterised by separate funding streams and budget constraints, which has led sectors to explore financing options in isolation from one another.

2.1.1 Fiscal space definitions

The fiscal doctrine in Western countries shifted after the Second World War from the balanced budget norm, whereby public expenditures were expected to match revenues, to active demand management, which warranted public sector borrowing to control aggregate demand (9). Together with the emergence of the welfare state, this confronted governments with increasing demands for public spending (9, 10). Low and middle-income countries are now faced with similarly high demands, coupled with households' limited capacity to cope with risk. As these economies grow, demand for public spending and the expansion of entitlements increase – also known as Wagner's law (9). All governments therefore routinely deal with the gap between projected revenues and expenditures, and how to fill it in the short and long run by creating 'fiscal space' (8).

The term 'fiscal space' is evolving and continues to be defined differently in the literature (11). Heller (2005) framed it as "the availability of budgetary room that allows a government to

provide resources for a desired purpose without any prejudice to the sustainability of a government's financial position" (1). Most definitions highlight the aspect of 'room' or 'space' in government resources, subject to maintaining 'fiscal solvency' or 'sustainability' (8, 9, 12).

The former points to the incremental nature of the concept (9), which reflects the reality of budgeting processes (13, 14). Although in theory, making resource allocation decisions for the total government budget at one point in time, based on the expected benefits of various investment options, may be more optimal; in practice, the largest share of resources have already been pre-committed in previous budgeting sessions and only newly available resources are being considered for allocation. Ambitious reforms to move away from this basis have encountered challenges, including programme budgeting (that breaks expenditures down by programme), or zero-based budgeting (that requires all expenditures to be justified for every new budgeting period) (9, 15).

The second aspect of fiscal sustainability requires that the additional room for spending is in line with the government's capacity (at least in the future) to continue financing its desired programmes, to service its debt obligations (including from borrowing) and to ensure its solvency (measured as the ratio of debt to GDP) (8). The IMF highlights that this will require: (i) a judgement of whether higher expenditure in the short-term, and any associated future expenditures, can be financed from current and future revenues; (ii) due attention is given to medium-term consequences of the spending for which fiscal space is created in a given year; (iii) any consideration of fiscal space must (at least) be made in the context of a medium-term expenditure framework that considers government's expenditure priorities comprehensively (8).

The World Bank and the IMF include an additional condition for fiscal space called 'macroeconomic space', whereby government spending can be increased without compromising macroeconomic stability (11). This prevailing approach has been criticised for conceptualising fiscal space only in residual terms and considering only short-term implications, which largely ignore the dynamic supply-side effects and developmental implications of higher government spending (16). For example, after the MDGs were set, there was concern about how large inflows of external aid would affect macroeconomic stability. This stemmed from the risk of the so-called 'Dutch Disease', whereby a large inflow of foreign currency was expected to lead to an appreciation of the local currency and thereby negatively affect exports and economic growth. However, the empirical evidence supporting the aid-induced Dutch Disease theory is inconclusive (11, 17, 18).

Fiscal space is by definition limited to public financing and therefore does not reflect the total resources available in a country for specific meritorious investments. Nonetheless, the focus on public resources is justified by the increased demand for and redistributive function of public spending (9), and the perceived complementary role of private investment (11). While the fiscal space concept is not particularly new, the term itself emerged quite recently in the context of low and middle-income countries and resurfaced in industrialised countries after the economic

crisis in 2008 (9, 15). It provides a useful framework to ensure that a comprehensive fiscal perspective is adopted and that linkages and feedbacks between options are duly considered when resources are allocated between various investment options (7).

2.1.2 Potential Sources of Fiscal space

There appears to be a relatively homogenous understanding of the potential sources for creating fiscal space at an aggregate national level and in the health, education, social protection and infrastructure sectors (1, 3, 19-21). According to a framework for OECD countries, the overall volume of fiscal space depends on: (i) national economic performance, (ii) the propensity of a government to tax; (iii) the propensity of a government to borrow; and (iv) the extent to which existing programmes claim incremental resources (sticky programmes and entitlements) (9). The latter implies that if the government's budget is committed to pre-existing liabilities, as may become the case with HIV treatment programmes, for example, there will be more limited (and potentially even negative) fiscal space in future budgets (8, 15).

In the context of the additional financing needs required in low and middle-income countries to meet the MDGs, the following options were considered central: (i) development aid and debt relief; (ii) domestic revenue mobilisation through improved tax administration; (iii) deficit financing through domestic and external borrowing; and (iv) reprioritisation and raising efficiency of expenditures (7, 16). The 2015 Addis Ababa Action Agenda on financing for development reiterates these financing sources for the ambitious Sustainable Development Goals (SDGs), and in particular, the need for increased domestic financing from strengthened tax efforts and innovative public and private financing sources (22).

In addition, several studies have explored the fiscal space available in specific countries for sector-specific investments. The IMF and the World Bank developed a framework for creating and assessing the potential availability of fiscal space for health, which includes: (i) conducive macroeconomic conditions, namely GDP growth and tax revenue; (ii) re-prioritisation of health within the government budget; (iii) earmarked resources for health, such as user fees, insurance premiums, earmarked taxes; (iv) health sector-specific grants/ foreign aid; and (v) efficiency gains (1, 3). The application of this assessment framework highlighted large variation in the potential of different sources across countries, given different economic fundamentals, political contexts and health system performance (3). Common findings across countries indicated that even where there was potential to create fiscal space from conducive macroeconomic conditions, this would only translate into effective fiscal space for health over time if the sector was more prioritised in the government budget and addressed its inefficiencies and absorptive capacity constraints (3). Optimising the use of existing resources appears critical, given that an estimated 20-40% of global resources dedicated to health are wasted (6). Earmarked development assistance for health remains an important source of fiscal space in many LMICs, but there are question marks regarding the extent to which it has truly been additional, or rather displaced government financing (23, 24).

In general, there is an implicit distinction between sources that are within the health sector's control, including earmarked revenues, grants and efficiencies; and those that are beyond its control, such as economic growth, government revenue generation and borrowing. The former are considered more feasible in that they are less dependent on broader economic conditions and the health sector's political capital (3). Indeed, while earmarked revenue and efficiency measures tend to be underemphasised at the aggregate level (11), they feature quite highly in sector-specific approaches (3, 25-27). Similarly, analyses within the sector envelope tend to explore various revenue streams on the one hand, and options to free up existing resources and reinvest them, on the other (3, 25, 28).

Although fiscal space can be viewed as a positive concept, and an economic variable that can be objectively measured, its application tends to require a composite approach that combines empirical observations and normative judgements (7). Indeed, estimating the volume of fiscal space from improved revenue generation, for example, requires the use of some benchmark or norm of what is considered an optimal or feasible level of government revenue compared to national income. Likewise, for sector-specific fiscal space, the potential from reprioritisation requires a normative judgment of how much a government *should* be prioritising investments in one sector over another. For example, the Abuja target whereby African governments committed to allocate 15% of their national budgets to health has become a normative threshold that was initially derived from the upper limit found in empirical data (3, 29).

WHO suggests that fiscal space analyses for health can serve a number of purposes, including as an advocacy tool to make the case for greater health prioritisation (30). Another use would be to explore the fiscal sustainability of alternative health reform packages, to ensure their current and future costs could be covered by current and future revenue streams (5, 6).

2.1.3 HIV Financing and Fiscal space

In the HIV arena, the unprecedented increase in external financing in the early 2000s limited the focus on budgetary fiscal space. More recently, a number of analyses have been conducted projecting the long-term financing needs of sustained HIV responses and these programmes' financial sustainability, especially in low and lower middle-income countries (4, 31-35). Generally, studies have estimated high gaps in low-income countries, such as Malawi, that cannot feasibly be filled through conventional domestic sources of financing (25), calling for more external resources (32). In terms of applying the fiscal space lens to HIV, few studies have done this, and even then, the focus has been on specific sources of fiscal space, rather than a comprehensive appraisal of available options.

Economic growth and the reprioritisation of health in national expenditures were considered in the aids2031 project, both for domestic and donor resources (36). Other studies have mentioned the potential of borrowing for certain countries (such as Botswana); improved

taxation and total government revenue generation; efficiency gains through more allocative efficiency, as well as reductions in leakages from poor governance (25, 28).

More recently, Resch and colleagues also highlighted the potential fiscal space for HIV from increasing the prioritisation of health in the national budget, as per the Abuja target of 15%, and the reprioritisation of HIV in the health budget (37). For the latter, they suggested that this share should be equivalent to at least half the relative HIV burden in a country's total burden of disease, and found significant potential to increase public HIV spending in this manner, although they did not explore the opportunity costs from disinvestments in other health programmes (37). Galarraga and colleagues (2013) developed a country classification framework to serve as a normative basis for establishing how much low and middle-income countries should contribute for the implementation of their HIV programmes, based on a "peer approach" (i.e. how much others are paying) (38). This framework could improve the efficiency of allocations, partly by ensuring that donor funds are additional to domestic funding rather than fungible (39, 40).

Other studies documented how certain innovative financing approaches were being tapped at the country level, in particular HIV-specific domestic taxation (41), such as the 3% AIDS levy applied to government departments in Zimbabwe (42, 43), despite the risk that they reduce the flexibility of fiscal policy (and are therefore unattractive to ministries of finance) and may not be additional resources as other budget allocations to HIV may be reduced proportionately (30). Some countries have also leveraged private sector HIV programmes, especially in the workplace (44), tapping risk-pooling mechanisms and using debt conversion schemes (Debt2health) (41, 45).

Finally, the UNAIDS investment framework highlighted the potential of creating fiscal space through allocative and technical efficiency gains (46), which respectively refer to the production of the right mix of interventions for maximum health gain, and the use of the least costly mix of inputs for a given level of health outcome (47). Schwartlander et al noted a discrepancy between the sources of new infections and the targeting of prevention programme resources, as have others (46, 48, 49), and large variations in unit costs between service providers (50-52). Using data envelopment analysis methods, Zeng et al (2012) found that in 68 low and middle-income countries, the average technical efficiency of implementing national HIV programmes was moderate (~50%), suggesting room for improvement (53). In a subsequent study, the fiscal space implications of these potential efficiency gains were incorporated into HIV resource needs estimates, demonstrating that with maximal efficiencies the annual resource needs in 45 countries would drop to USD 6.3 billion instead of the UNAIDS USD 13.5 billion projection (54). The main options being considered and in some cases tested to reap technical efficiency gains are programme scale-up, service integration and task-shifting (55, 56). In line with the broader aid effectiveness agenda, studies have indicated that donor harmonisation and alignment to government priorities and systems could generate further gains through greater allocative efficiency and reduced transaction costs (57-60).

Interest in analysing and estimating the fiscal space for HIV programmes has increased, but existing studies have each limited their analyses to specific sources, and the prevailing sub-sector approach has excluded revenues for or efficiencies from investments beyond the boundaries of the HIV programme or the health sector. In fact, some methods have further isolated HIV fiscal space from fiscal space for health, with the inclusion of HIV prioritisation within the health budget as an additional lever (37).

2.1.4 Limitations of the fiscal space framework for HIV

There are a number of weaknesses in the framework used to assess sector-specific fiscal space in particular. Firstly, fiscal space analyses tend to be one-directional, with no or limited consideration of the feedback loops through which higher government spending could have supply-side effects, such as relaxing key bottlenecks or creating additional productive capacity (8), leading to economic growth and thus additional fiscal space in the medium to long run. Spending now could also offset potential costs and entitlements in the future (7, 16, 61). Although the report to the Development Committee of the World Bank and IMF recognised that "the sustainability of policies to create fiscal space is a function of what the fiscal space is used for", Roy et al (2007) remark that the focus is still on short-term macroeconomic stability, whereby the short-term acts as a binding constraint on the long-term (16). To address this, sophisticated dynamic general equilibrium models have been developed to incorporate the macroeconomic impacts of scaled-up government development and health spending (3, 62, 63). However these models are not commonly used for sector-specific fiscal space assessments, and tend to be viewed by policy-makers as black boxes (64).

A second limitation is that resources spent in other sectors with different primary objectives are not considered relevant for the target sector's fiscal space. Heller (2005) highlights that fiscal space cannot be viewed solely within the boundaries of a specific sector given the cross-sectoral and intertemporal implications of government expenditures (1, 8). High spending in one sector can also have ripple effects in others, through public sector-wide demands for higher wages following salary top-up in HIV/health programmes, for example (8, 65, 66). Moreover, evidence of aid fungibility could imply that the additional fiscal space created by external development assistance is more limited, and therefore its contribution to fiscal space for health will depend on what the displaced government funding is reallocated to, and how those investments impact on health outcomes (67). Yet current assessments do not incorporate such non-primary sector spending, largely reflecting the exclusion of cross-sectoral synergies from resource allocation frameworks. As discussed below, this is of concern to the HIV response, given the multiple impacts of non-HIV interventions on HIV outcomes and vice-versa.

A third limitation is the apparent disconnect from the issue of absorptive capacity, which constrains effective fiscal space. Systemic bottlenecks and weak capacity are mentioned as a key area to use fiscal space to invest in, but they are not considered to be determinants of effective fiscal space (2). The focus in the development and public finance literature tends to

be on budget management and revenue mobilisation capacity, not the other binding resource constraints in sectors like health (11, 61). A country's ability to create effective fiscal space for HIV or health more broadly is closely related to its absorptive capacity, which depends on factors such as the availability of skilled human resources, physical resources (infrastructure) and good governance (68, 69). Low absorptive capacity and the annual under-spending of health budgets in many low-income-countries has been thought to explain the reluctance of ministries of finance to allocate more resources to health and the channelling of development assistance through vertical programmes. Given other structural binding constraints, large increases in funding may not be enough to ensure programme scale-up (68, 70).

The focus of this research is on the second and third limitations, namely whether and to what extent complementary investments in broader development programmes and health system strengthening could represent potential sources of fiscal space for a specific programme area like HIV, and how this could be measured and incorporated in current fiscal space assessment methods.

2.2 Resource allocation and economic evaluation of interventions with multi-sectoral outcomes

For the search on economic evaluation methods for interventions with multi-sectoral benefits, the review started from standard health economic evaluation textbooks and guidance, namely Drummond et al (2005), the International Decision Support Initiative's Reference Case for economic evaluation in global health and the first and second US panel on cost-effectiveness analysis for health and medicine (7-9, 71). This was supplemented with an electronic database search of three databases (Pubmed, Econlit, Googlescholar) combining 'economic evaluation', 'cost-effectiveness', 'cost-consequence', 'cost-benefit', 'return on investment' or 'societal perspective'; and 'public health', 'non-health intervention', 'health promotion', 'multi-sectoral', 'inter-sectoral', 'cross-sectoral', or 'non-health outcomes' in title searches. There was no geographic or publication date restriction, but only publications in English, French or Dutch were considered. Publications were included if they reviewed methods or methodological challenges in the economic evaluation of health-related interventions with non-health outcomes, or presented new methodological approaches.

This section summarises the available approaches to assessing the economic value of investments in non-HIV interventions, which can be sub-divided into approaches that are embedded in a welfarist theoretical framework, and those that pertain to the extra-welfarist domain, as described below (72, 73).

2.2.1 Efficient Resource allocation and Welfarist theory

Public policy and finance are underpinned, at least in part, by the theoretical framework of welfare economics, whereby resource allocation is to be determined by the optimisation of a social welfare function (74). Social welfare is typically defined as a function of individual utility derived from the consumption of goods and services, and could be maximised in aggregate terms following utilitarian principles, or maximised for the least well-off individual following prioritarianism and the Rawlsian principle of social justice (75, 76). Welfare economics aims to provide a coherent ethical framework to ascertain which states of an economy are more socially desirable than others (76). It is driven by the concept of Pareto-efficiency, whereby a resource distribution is considered optimal when it is not possible to make anyone better off without making someone else worse off (77). Under competitive market conditions, individuals would identify Pareto improvements and engage in voluntary trade until the economy would be expected to reach a general Pareto-optimal equilibrium. Even with market failures, public planners could use this efficient allocation to derive optimal taxation and subsidisation policies (78).

There are four central tenets of neo-classical welfare economics (72). The first is the principle of utility, as the end that individuals seek to maximise, and a reflection of the satisfaction of their preferences. The second is the principle of individual sovereignty and the idea that individuals are the best and only judges of their welfare. Thirdly, it is assumed that utility can only be derived as a consequence of the outcomes of consumption and not from the process or the capability, also known as consequentialism. Fourthly, welfarism and the Pareto principle define the social desirability of any reallocation of resources based on the utility levels attained, as described above (72). Importantly, welfare economics makes no value judgment about the initial allocation or distribution of resources and only considers the desirability of reallocations (74).

Cost-benefit analysis (CBA) has been developed as a tool to guide such allocations (79). Indeed, CBA is rooted in welfare economics and the more realistic and less-restrictive *potential* Pareto-improvement criterion, as it posits that a programme is welfare-enhancing if the benefits exceed the costs and thus the gainers would potentially be willing to compensate the losers, bringing the equilibrium closer to the Pareto-optimum (80). Neo-classical welfare economics avoids interpersonal comparisons of welfare and utility, since individuals' utilities can strictly speaking only be ranked, and not measured cardinally (81). The potential compensation criterion underlying CBA, however, implies that utility across individuals can be valued and aggregated (82).

A key characteristic of CBA is that it assumes that the budget constraint is endogenous, rather than exogenously fixed (83). Therefore, in theory, decisions about the size of the relative public resource envelope for each sector would be determined through some form of CBA that seeks to optimise allocative efficiency. Once public planners have decided how much of each sector's

public goods and services would be optimal to produce to maximise social welfare, decisions at the sectoral level would be expected to be made from a technical efficiency perspective. This would imply that they should seek to produce their intermediate outputs (sector-specific goods and services) with the fewest resource inputs. While sectoral allocations would need to satisfy the condition of general Pareto-equilibrium, allocations of sector budgets to different interventions would only involve partial equilibrium analyses.

2.2.2 Economic evaluation methods for interventions with multi-sectoral outcomes

Evidence from economic evaluations is meant to inform the operational prioritization of interventions representing the best value for money, based on the comparison of the costs and consequences of different intervention options. Different types of economic evaluation methods exist, each responding to specific objectives and of relevance to different levels of decision-makers (see Table 2.1) (84, 85). There is general consensus in international guidance documents that non-health outcomes should be taken into account in these analyses to reflect a full societal perspective (86, 87).

Conventional guidance on evaluating interventions with multi-sectoral outcomes has been to conduct a CBA (80). This would require estimating all the direct and indirect economic costs of alternative intervention options on the one hand, and their benefits on the other. All benefits, regardless of which sector they fall in, would then need to be translated into monetary values, based on individuals' willingness-to-pay (WTP) for each of them (88). Conceptually, this is measured as the increase or decrease in individual wealth that has an equivalent effect on the individual's wellbeing, as the change in circumstance resulting from the intervention. This individual WTP can be for the consumption of a good or service, the probability of experiencing morbidity from a specific disease, or any other change that is in the individual's welfare function (89).

These WTP values can be measured from market transactions or observed behaviours, following Samuelson's revealed preference approach, whereby individuals' choices to consume certain goods and services reveals their marginal valuation of each (90). Alternatively, stated preference methods can also be used to elicit and derive marginal utility gained from the consumption of goods or services that produce health, as a measure of individual WTP for health vis-à-vis other consumption options (78, 91).

CBA provides a method to summarise information about intervention consequences and their likely magnitude (89). Although the major advantage of its monetised outcome is its ability to incorporate a range of cross-sectoral benefits, its major limitation is its measure of outcome as utility alone. Following Sen's seminal work and critique of utility as social welfare, there is a growing literature and area of research on redefining social welfare to include procedural utility (in addition to utility derived from consumption), as well as broader measures of wellbeing,

social benefits and capabilities (72, 73, 92, 93-96). Such measures could be used to value interventions and capture their multi-sectoral outcomes more holistically.

Another related critique of CBA and welfarism is that they do not adequately reflect the decision-maker's perspective and societal objectives, which tend to recognise the existence of merit goods or basic goods that ought to be subsidised by the state or allocated under more egalitarian principles, rather than relying on utilitarianism and potential Pareto improvements (72, 97-99). An extra-welfarist framework has therefore been developed to better reflect the evaluative space and principles of resource allocation in health care. It is characterised by a rejection of utility as the sole measure of social welfare, and Paretian indifference to different distributions of wealth, as well as a departure from the principles of individual sovereignty (72). In extra-welfarism, health is the maximand of social decision-makers, and interpersonal comparisons are possible and indeed central to resource allocation decisions (72, 100).

This extra-welfarist framework is widely considered to be the foundation of most applications of economic evaluation in health (73). The health sector and HIV sub-sector tend to use cost-effectiveness analysis (CEA) or cost-utility analysis (CUA) in decision models (101). While the former considers natural units as its measure of outcome, such as HIV infections averted or AIDS-related deaths averted, the latter uses a summary measure of health that captures both quantity and quality of life, namely Quality-Adjusted Life Years (QALYs) gained or Disability-Adjusted Life Years (DALYs) averted. It is worth noting that despite this clear distinction, cost-effectiveness analysis is often used to refer to both CEA and CUA.

Depending on the approach adopted, the cost-effectiveness ratio (CER) estimated through an economic evaluation is compared to the next best use of resources or a normative benchmark to guide the resource allocation decision. The normative benchmark approach assigns a threshold, or ceiling ratio, that defines acceptability (102). Such thresholds are used to determine whether an intervention or programme is good value for money and whether it is worth funding. The principal thresholds that have been in use are for cost-utility ratios, namely the cost per DALY averted or QALY gained, and are either rather arbitrary or based on a human capital approach that reflects averted productivity losses (103-109). Normative World Bank and WHO thresholds, expressed as a function of national income, have tended to be used as benchmarks in the HIV arena (110, 111), as an indicator of budget holders' WTP for interventions (106, 112).

There has been substantial scholarly debate about what this threshold represents, and much of it stems from the different theoretical frameworks of CBA and CEA. There is a growing consensus that it is an empirical measure of supply-side opportunity cost, and therefore needs to be estimated by measuring how much health gain the health budget is currently achieving at the margin (72, 100, 113, 114). If interventions were perfectly divisible, had constant returns to scale, and were ranked by their cost-effectiveness ratio, the most cost-effective interventions should be prioritised and implemented until the health budget was exhausted – this is the so-

called league table approach. In this case, the cost-effectiveness ratio of the last implemented intervention would be the cost-effectiveness threshold, or the shadow price of the health budget constraint (113, 115). This measure of opportunity cost also reflects the valuation of health outcomes that is implied by the current allocation of resources.

Table 2.1. Economic evaluation methods, decision rules and implications for interventions with multi-sectoral outcomes

Method	Outcome unit	Implications for interventions with multi-sectoral outcomes	Decision rule(s)
Cost-Benefit Analysis (CBA)	Monetised outcome	Benefits from all sectors can be accounted for and monetised	Every intervention option where Benefits > Costs (or Benefit-Cost Ratio>1) In a ranking, interventions with the largest net benefit should be prioritised
Cost-Effectiveness Analysis (CEA)	Natural unit e.g. HIV infection averted or AIDS death averted	Considers variations in effectiveness between intervention options But single outcome analysis impedes the incorporation of multiple outcomes within HIV (treatment and prevention interventions cannot be compared) and beyond HIV	Intervention with the lowest cost-effectiveness ratio (CER) Rank interventions from lowest to highest CER in a league table and allocate fixed budget starting from the lowest CER until the budget is spent
Cost-Utility Analysis (CUA)	Disability-Adjusted Life Year (DALY) Quality-Adjusted Life Year (QALY)	Allows for HIV-wide and health sector wide comparisons But single health outcome makes it difficult to take non-health outcomes into account	Intervention(s) with the lowest CERs and league tables (see above) Below $25-150/DALY averted in LICs and $100-500/DALY in MICs (World Bank) Below 1x or 3x GDP/capita per DALY averted (WHO) Supply-side empirical cost-effectiveness threshold
Cost-Consequence Analysis (CCA)	Multiple natural units	Used to present multiple outcomes, where CBA is not feasible Does not combine measures of benefit into a single measure so cannot be used to rank	No rule

The literature highlights several limitations of CEA methods for interventions with multiple and cross-sectoral costs and consequences, including public health interventions and health-producing interventions outside the health care sector (85, 96, 116-120). First and foremost, CEA does not enable non-health outcomes both within and beyond the health domain to be measured and valued (116). Similarly, costs incurred by other sectors are not typically taken into account, which may be important when investments or disinvestments in a public health intervention increase the need for education, social care or criminal justice expenditures, for example (121, 122). Secondly, many of these interventions are difficult to evaluate in a

randomised controlled trial setting, or have long-term benefits that cannot be captured in a trial context, leading to concerns around attribution of effects (116). This is further heightened when considering the costs and challenges of conducting inter-sectoral evaluations with multiple endpoints (123). Finally, CEA is primarily concerned with evaluating the efficiency of alternative investments, and does not directly consider equity objectives in its constrained optimisation paradigm (116, 124).

An alternative to CEA that seeks to address the limitations of focussing on a single outcome and a single policy objective (i.e. efficiency) is cost-consequence analysis (CCA), whereby all costs and outcomes of alternative interventions are presented separately for the decision-maker's consideration (80). Indeed, several current guidance for health economic evaluation recommend CCA approaches in reporting, whereby the non-health costs and effects are to be disaggregated by sector of the economy or payer. This so-called 'disaggregated societal perspective' is the seventh principle of the International Decision Support Initiative's Reference Case for economic evaluation in global health (71). In England and Wales, the National Institute for Health and Care Excellence's (NICE) guidance for local authorities also explicitly refers to CCA to guide decisions at this level, in part because it captures spill over effects on other areas of local government responsibility (125). Recently, the second US panel's recommendations on cost-effectiveness analysis in health and medicine even recommended the standard reporting of two reference cases for every economic evaluation: one from a health care sector perspective and one from a broader societal perspective, with the use of an impact inventory to comprehensively report consequences beyond the formal health care sector (126). However, even with impact inventories for interventions across sectors, there is very limited guidance on which inter-sectoral costs and benefits to include (122), and more importantly on how a health payer should value non-health effects, as part of its decision on how to allocate its resources most efficiently.

Besides taking the single outcome framework of CBA or disaggregated CCA, another approach has been proposed by Claxton and colleagues, whereby an intervention is worth funding if other sectors could compensate the implementing sector for their benefits or be compensated for their costs (127). This sits within an extra-welfarist framework, as the authors argue that a welfarist societal perspective would not be sufficient for the evaluation of interventions with multiple objectives and impacts on multiple constraints beyond the health sector. The latter reflects a situation where a single public payer can set its budget and allocate resources within it, based on the societal returns of intervention options. This implies an endogenous budget constraint. However, in practice, most decision-makers are faced with an exogenous fixed budget constraint, and are only mandated to allocate it within their sector, and not across sectors.

The approach therefore values the outcomes in each sector by the shadow prices of the sector's budget constraint, and provides a clear decision rule for health and non-health payers. The strength of this approach is that it reflects the distinct evaluative spaces of each sector and

its respective budget, and it is potentially a practical way of evaluating investments in interventions with multi-sectoral costs and benefits, without going down the route of complex mathematical programming to maximise multiple objectives, subject to multiple budget constraints (127). However, Claxton and colleagues suggest that it would be infeasible to operate such inter-sectoral transfers in real-world resource allocation, and that they may have high transaction costs. Their proposed compensation is therefore more of a hypothetical or potential compensation test, rather than the basis for an actual decision for cross-sectoral financing.

One limitation of this approach is that it assumes that the current allocation of resources to each sector is optimal, or at least that it is fixed and cannot be changed. Since the shadow price, or the valuation of each unit of outcome, is a function of the sector's current budget constraint, this directly influences the financing decision. Another implicit assumption of the potential compensation test is that although each sector is aiming to optimise its sector-specific objective (e.g. health gain or education gain), it would also value spill overs on other sectors' objectives, as much as the other sectors do, and would factor them into its funding decision. For example, this would mean that a health payer would value education outcomes as much as the education payer's current marginal productivity (and thus revealed WTP for a unit of education outcome). This health payer would therefore be willing to internalise education externalities, even at the expense of its own health objectives.

In practice, the most applied approaches in the HIV field have been CEA and CUA (111, 128-130). A bibliometric review of economic evaluations in global health reported that the majority of studies in low and lower-middle-income countries were for HIV interventions, and just under half of the studies from these countries were CEA and a nearly equivalent amount were CUA (131). The application of CBA methods has been rare (89), with the notable exception of the work commissioned by the Copenhagen Consensus Centre in 2011 to assess the benefit-cost ratios of a range of prevention, treatment and structural HIV interventions (132). However, no applications have been found to date of Claxton et al's compensation test approach.

In summary, CBA is the most commonly recommended approach for interventions with multi-sectoral outcomes, but it is also the least used, due to its different theoretical framework and critiqued outcome measure. CEA and CUA are preferred in health and in HIV, despite the recognised limitation of their decision rules based on single-outcome analysis frameworks and their concomitant undervaluation of interventions with multiple cross-sectoral outcomes (119, 120). A theoretical approach has been proposed to deal more pragmatically with multiple decision-makers in health and non-health sectors, with their own fixed budget constraints and separate objective functions, but despite its more accepted extra-welfarist basis, it has not been applied. For such an approach to be used, an even more realistic approach is needed that recognises the separate evaluative spaces of each sectoral decision-maker and does not impose non-health sector objectives on health payers.

2.3 Inter-sectoral governance and financing mechanisms for health

For the literature search relating to cross-sectoral governance structures and financing mechanisms for health, the WHO website and two electronic databases were searched (Pubmed, Google Scholar) with the following search terms: 'social determinants of health', 'health promotion', 'primary health care', 'HIV', 'AIDS'; and 'inter-sectoral', 'cross-sectoral', 'multi-sectoral', 'interdisciplinary'; and 'health in all policies', 'mainstreaming', 'governance', 'whole of government' and 'joined up government', 'co-financing', 'joint budgeting', 'pooled budgets'. There was no geographic or publication date restriction, but only publications in English, French or Dutch were considered. Publications were included if they reviewed, described or evaluated governance or financing mechanisms to coordinate action on health across sectors.

There is broad recognition in public health of the need for multi-sectoral action to address the social determinants of health (118, 133). The World Health Organisation and governments acknowledge the fact that the health sector alone cannot change lifestyles, gender and socio-economic inequalities, or working and environmental conditions that shape health-related behaviours and outcomes (134, 135). Several policies in non-health sectors are likely to have health impacts and implications for health care use, just as public health interventions can have downstream socio-economic impacts. Yet the institutional frameworks and siloed nature of government sectors make it problematic to assume that non-health sectors will consider the externalities of their policies and programmes on health, and vice versa (118). In response to these challenges, policy responses have been devised to facilitate inter-sectoral approaches that incentivise non-health sectors to internalise health externalities, mainly in the form of governance arrangements and coordination structures. Some also extend this stewardship and coordination function to include a financing function with specific financing mechanisms (118). This section summarises the literature on approaches to govern and resource interventions requiring inter-sectoral action for health.

2.3.1 Governance mechanisms for inter-sectoral collaboration

Several terms have been used to describe inter-sectoral governance frameworks, including joined-up government and whole-of-government approaches, which are increasingly popular and reflect a growing understanding of the complexity and interconnectedness of many policy issues. The rationale underpinning these frameworks is fundamentally about policy coherence, and optimising service delivery efficiency through integration (118, 136, 137).

In health, the underlying principle has been labelled as 'health in all policies' (HiAP) and can be defined as a policy practice of integrating or internalizing health in other policies that influence the social determinants of health. Indeed, following this approach, policy-makers are expected to consider health in the development, implementation and evaluation of policies outside the traditional health sector. The 2010 Adelaide Statement on Health in all Policies described it as

"shared governance for health and well-being" (135). In the HIV field, it is similar to the principle of mainstreaming (138), which UNAIDS has defined as "a process that enables development actors to address the causes and effects of AIDS in an effective and sustained manner, through both their usual work and within their workplace" (139). Although the HIV response distinguishes between an internal organisational response to HIV in the workplace, and an external programmatic response in the development sector's 'core business', the latter is most relevant to this thesis.

This HiAP approach essentially serves as a strategy to ensure that non-health sectors take on a health mandate and therefore include health objectives in their decision-making. From an economic perspective, this would imply that these payers allocate their resources in such a way as to optimise their own objective, as well as a health objective (140). To ensure this happens, institutions and incentives need to be aligned. As put forward in the Adelaide statement: "to harness health and well-being, governments need institutionalized processes which value cross-sector problem solving and address power imbalances. This includes providing the leadership, mandate, incentives, budgetary commitment and sustainable mechanisms that support government agencies to work collaboratively on integrated solutions." (135)

Most of the literature and experiences with HiAP has originated within the field of health promotion, which has been geared towards enabling and incentivising individuals to pursue health-promoting behaviours and be more effective producers of health (118, 141, 142), with due recognition of the non-health care inputs that go into this production function (143).

Governance tools that foster coherence, collaboration and partnership can be classified into four categories: those related to structures; processes; financing; and mandates (144). A review conducted for the WHO European Region indicated that HiAP has primarily manifested through a number of governance structures at five different levels (118):

- *Government-level*: cabinet committees and secretariats represent the highest decision-making bodies of government, and have been used to facilitate interdepartmental dialogues on health issues or to include health considerations in other policy decisions. Despite their confidential nature, anecdotal evidence suggests that they may be key to enable and mandate interdepartmental cooperation on issues of high political importance.
- *Parliament-level*: parliamentary committees around health issues can be effective at enhancing the prioritisation of an issue and sustained pressure for action to be taken, as observed with the scrutiny processes around the health inequalities agenda in England through the House of Commons Health (Select) Committee in 2009 and the Auditor-General's report to the Victorian Parliament in Australia in 2007, for example.
- *Bureaucratic-level (civil service):* At this level, ministry mergers or mega-ministries have led to formal re-structuring in order to re-align institutional objectives for cross-sectoral

planning and programming. Also, inter-departmental committees have been formed as a bureaucratic mechanism to convene different departments around a shared priority. In national HIV responses, several affected countries established National AIDS Coordinating Authorities (NACAs) to coordinate their national HIV responses and elevated them to the supra-ministerial level under the executive office of the president or prime minister (145). These have performed relatively well, but they have lacked the incentives to hold other sectors to account in their commitment to mainstream HIV in their own policies and programmes (146).

- *Engagement beyond government:* public engagement, stakeholder engagement and industry engagement have mobilised support and resources for collaborative action by government and non-governmental actors on cross-sectoral health issues. Broad stakeholder and civil society engagement has been a key tenet of the multi-sectoral HIV governance structure, largely promoted and imposed by international donors in LMICs, through the World Bank Multi-sectoral AIDS Programme (MAP) and the Global Fund's Country Coordinating Mechanisms (CCMs) among others (147, 148). These mechanisms have been more effective at involving non-state actors in HIV responses, while the participation of non-health government departments has remained limited (146, 149).
- *Managing funding arrangements:* joint budgeting or delegated financing mechanisms are governance structures that organise the resources of inter-sectoral action and can serve as an incentive or vehicle for joint action. These will be discussed in detail below.

Overall, the literature on the effectiveness of inter-sectoral governance structures for health is scant but growing, along with policy-makers' experimentation with governance structures that can prompt or sustain inter-sectoral action (118, 150-156). Lessons learned to date reflect the need for multi-level mechanisms and the importance of strong leadership and political will, which may be triggered by a compelling framing of the immediacy of the problem at hand (118, 136, 140, 150). This echoes the experience in the AIDS response, which was able to garner global political attention and commitment to multi-sectoral action when it was tabled at the United Nations as a security issue (157). While government and parliament level mechanisms may have more political clout and authority to drive such agendas, they may not systematically take on health issues or inter-sectoral action for HIV, which is where mechanisms to engage the public and other stakeholders for advocacy would be important (145, 156).

The most common inter-sectoral governance structure for health and HIV has been inter-sectoral planning and coordination committees, but these have typically lacked strategies for accountability, monitoring and evaluation, and resourcing (158). Moreover, they have had limited political influence, power and incentives to effect systemic changes (146, 150). There is a potential misuse of the inter-sectoral argument if the governance structures are divorced from

the underlying motivation, values and power relations, thereby formalising a shallow consensus of partnership (137, 159, 160).

The next section reviews financing mechanisms that have been explored and tested, as a means to incentivise and organise inter-sectoral actors for joint action for health.

2.3.2 Financing mechanisms for inter-sectoral collaboration

In addition to governance structures, processes and mandates, the financing tool or function has been found to be critical for HiAP initiatives. Indeed, once political will for inter-sectoral action is in place, the availability of resources can be pivotal, and the availability of multiple sources of funding may be particularly beneficial if it increases participation across government (140). To deal with the inefficiencies, fragmentation and missed opportunities of vertical funding silos, examples can be found particularly in high-income countries where sectors have been co-financing integrated care and health promotion interventions that aim to generate multiple cross-sectoral benefits. These financing mechanisms can be categorised as joint budgeting or delegated financing.

Joint budgeting mechanisms have been developed in Australia, Canada, England, Italy, the Netherlands and Sweden, whereby budgets across government departments or tiers are shared or integrated to address shared goals (161). These can be either voluntary or mandatory, and may be one-off initiatives or long-term processes of organisational change. Joint budgeting can take various forms (118):

- Budget alignment, whereby one budgetary authority manages multiple budgets for agreed goals;
- Dedicated joint funds that multiple departments contribute for specific joint activities;
- Joint-post funding whereby a position funded by multiple departments with cross-sectoral responsibilities;
- Fully integrated budgets whereby resources and workforce come together under one ‘host’ department; and
- Policy-orientated funding whereby resources are allocated by a central or local authority to policy areas rather than to sectors

These initiatives have tended to focus on easily identifiable beneficiary groups that require more than health care for their well-being and would benefit form a continuum of social services, including social care, education, housing and employment (123, 162-167). Well-documented examples from Sweden include a rehabilitation programme for people with musculoskeletal disorder, an elderly safety promotion programme and a diabetes prevention programme (163-165, 168). These were evaluated in the context of Sweden’s trial legislation in 1994, allowing social insurance, social welfare and health care services to pool budgets under joint political steering. In their evaluation, Hultberg and colleagues found positive results on the perceived quality of interdisciplinary and inter-organisational collaboration in the co-financing model, but

no positive impacts on patient outcomes, such as number of sick days taken by people with musculoskeletal disorders, or health care costs, since patients in the intervention sites had significantly more contacts with physiotherapists and physicians than those in the control sites (162, 166).

In the UK, joint budgeting has been undertaken for health and social care services for older people, and for health, education and social services for children that were jointly managed by NHS primary care trusts and local councils (169, 170). The latter were perceived to improve the efficiency of services and care pathways (169). In New Zealand, regulation was put in place to allow for joint budgeting of 'clustering projects', with some evidence of success when pooling resources from local health boards, nutrition agencies, NGOs and the fitness and food industry to promote healthy lifestyles (161).

Another financing model is delegated financing, which has been primarily implemented through health promotion foundations, which are statutory bodies with long-term and recurrent public resources dedicated to funding cross-sectoral health promotion programmes. Initially established in Australia from a dedicated tobacco tax, this model was replicated in Austria and Switzerland, tapping various funding sources, such as an additional levy on top of compulsory health insurance premiums or a dedicated sum from sales-tax revenue (171). The institutional challenges encountered related to the implications of statutory bodies on government stewardship, and the perceived free-rider problem that has been found to hinder co-financing mechanisms (171).

Overall, there is to date limited evidence on the effectiveness of such co-financing arrangements on health and other outcomes, besides an experience with transport safety in the UK where casualty rates were significantly reduced (118). Since their effect on costs is also unclear, the cost-effectiveness of these mechanisms remains uncertain. However, there is some evidence of impact on process measures and greater potential at local levels of government (161). Also, while health promotion typically receives very minimal funding, there is some indication that co-financing mechanisms may have mobilised additional resources (171).

The evidence base suggests that the factors that facilitate the success of these schemes is the establishment of regulatory and legislative frameworks providing incentives and allowing budget-sharing. Clear accountability for actions is critical, as is the identification of specific benefits for all participating sectors through win-win strategies (161, 172). When considering the importance of economic evidence and arguments for inter-sectoral coordination, Drummond and Stoddart (1995) also suggested that inter-sectoral economic evaluations could increase awareness among decision-makers of the non-health sector alternatives and their marginal benefits for health (123). However, they also highlighted that these analyses were unlikely to provide a "complete technical solution", given institutional cooperation challenges. Indeed, the institutional barriers or disincentives to engage in cross-sectoral co-financing can

stem from a lack of trust among sectoral actors, an imbalance in financial contributions, and fear of loss of autonomy or budget control (140, 150, 161, 173).

2.4 Summary of Research Gaps

The literature review identified a number of gaps, which this thesis sought to address.

First, in a time of resource constraints and competition between sectors for scare public resources, there are surprisingly few theoretical and empirical analyses of how investments in non-HIV sectors or interventions could contribute to HIV outcomes and therefore be a financing source to leverage more efficiently. Indeed, standard fiscal space analyses that seek to estimate the resource envelope for HIV objectives, pay little attention to the value of health system strengthening and broader development interventions. New methods or methodological adaptations of sector-specific fiscal space analysis are required that consider and build in non-HIV and non-health sector investments, where these are expected to have downstream benefits for HIV. The HIV value of effective investments in such programmes would need to be quantified and compared to other sources of fiscal space for HIV, to gauge the relative size of efficiency gains from non-HIV investments.

Secondly, most critiques of the use of existing single outcome economic evaluation frameworks for complex or structural interventions focus on how value is measured (96, 119, 174), rather than how costs are apportioned and factored into the equation underlying prioritisation. The approach this research sought to investigate further was how the costs of these interventions could be shared across benefiting sectors, and such co-financing were genuinely – not hypothetically – considered in each sector's decision frame (175). There is need for the empirical application of the analytical compensation approach to an implemented intervention, as well as further methodological development to position it as a cross-sectoral financing mechanism.

Finally, although it is recognised that resource allocation decisions are political and cross-sectoral investments institutionally challenging, there is limited empirical evidence on the incentives and barriers that prevent greater cross-sectoral collaboration in the context of HIV, especially in low and middle-income countries. It is therefore difficult to determine how likely they are to impede the feasibility of a potentially efficiency-enhancing approach, and through what mechanisms these could be overcome.

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CHAPTER 3 METHODS

3.1 Study Approach

The overall aim of this thesis was to develop and explore the application of a novel method for the economic evaluation and fiscal space analysis of interventions with multiple benefits across multi-sectoral payers, in the context of HIV. The specific objectives to meet this overarching aim involved the development of the method on the one hand, and the demonstration of its applicability on the other.

Based on the gaps identified in the literature review in Chapter 2, the focus of the study was to further develop and extend existing methods in fiscal space analysis and economic evaluation. Building on theoretical work accounting for cross-sectoral transfers in resource allocation, the method development required an empirical proof-of-concept and stylised examples to illustrate the methodological extensions proposed and to demonstrate the efficiency gains and relevance of the approach for the economic evaluation and financing of existing structural interventions for health in general, and HIV in particular. The choice of methods for this component was therefore derived from the economic methods in use.

The applicability of the proposed approach was subsequently explored in terms of its analytical applicability, as well as its institutional feasibility as a financing mechanism. The former was demonstrated by conducting extended fiscal space analyses and cross-sectoral co-financing analyses with empirical data. The latter was investigated by eliciting and analysing the perspectives of decision-makers.

The study adopted a mixed methods approach to meet the overall study aim, including both quantitative and qualitative data collection and analysis. Mixed methods research has been defined as: “research in which the investigator collects and analyses data, integrates the findings, and draws inferences using both qualitative and quantitative approaches or methods in a single study or a program of inquiry” (1). Although there are weaknesses to mixed methods approaches related to the rigour with which they are applied and their differing epistemological paradigms (2, 3), they are also recognized and valued for providing more comprehensive analyses that further interrogate, verify and validate data (4, 5). In this thesis, quantitative or qualitative methods were selected depending on the specific research objective, and based on which method was best suited to address the question at hand. The methods were then considered as complementary and integrated at the interpretation stage, when examining the analytical application and feasibility of cross-sectoral and cross-budget co-financing (6).

Fully recognising that there is substantial variation between countries in sub-Saharan Africa (SSA) and their HIV epidemics, economic fundamentals, fiscal burdens and ability or options to generate resources for HIV, the study included both cross-country analyses and specific

country case studies focusing on Tanzania and Malawi. The strength of cross-country analyses is their ability to provide statistical power in investigating and quantifying the relationships between macro-level factors, such as public HIV spending and national fiscal indicators amendable to policy change (7). They are also useful to illustrate in quantitative terms how different characteristics between countries influence financing outcomes, including how countries with different types of HIV epidemics or levels of economic development will value the co-financing potential of structural interventions differently. However, the main limitation of such cross-country analyses and comparisons is their implicit assumption of structural homogeneity, and their lack of depth and contextualisation (8, 9). Case studies, on the other hand, may yield deeper insights and highly context-specific findings, but therefore lack generalisability (10), even though it has been argued that they can provide conceptual rather than statistical generalisability (11-13). Again, the selection of either approach was based on its ability to meet each study objective (see Table 3.1).

Table 3.1 Summary Methods

Objectives	Chapters	Methods
1. To develop a methodological approach – 'co-financing' – for factoring in non-HIV benefits and non-HIV payers in the decision rules of resource allocation.	4	Case study with trial-based economic evaluation modelling
	5	Literature review with stylised example
2. To explore the potential of creating fiscal space for HIV across sub-Saharan Africa, incorporating the value of co-financing in health system strengthening and broader development investments.	6	Expanded fiscal space analysis Cross-sectional econometric analysis
3. To apply the co-financing approach by assessing the benefits and potential of co-financing of a food support intervention in various country settings.	7	Model-based economic evaluation in multiple settings
4. To understand in practice the institutional barriers, enablers and (dis)incentives to adopting a co-financing framework in HIV financing and priority-setting.	8	Qualitative case study with in-depth interviews

The details of the methods adopted are presented in each of the five results chapters (Chapters 4-8) and in three accompanying technical appendices. This section provides an overview of these methods, their strengths and limitations. It starts by describing the study context, followed by a description of the conceptual framework that underpins the methodological approach. Next, the methods used to achieve each objective are covered. Finally, the ethical considerations and funding sources are presented.

3.2 Study Context

The analyses in this thesis focused on sub-Saharan Africa, as the region most affected by the HIV epidemic, combined with high levels of poverty and several development challenges. Eastern and Southern Africa is home to 19 million PLHIV – about half the global burden, and had an estimated 960,000 new HIV infections in 2015. It is also the region that has led the most rapid increase in ART coverage from 24% in 2010 to 54% in 2015 (14). There is significant variation in the size and types of epidemics across and within these countries. Similarly, countries differ in their level of economic development, with a mix of low, lower-middle and upper-middle income countries, their systems and quality of governance, and their dependence on external financing (15, 16). The cross-country analyses considered the 14 countries (or a sub-set) in SSA with the largest HIV burdens in absolute numbers of PLHIV, as well as all hyperendemic countries (>15% prevalence), given the fiscal pressure to increase and optimise HIV spending alongside many development priorities.

The country-specific work concentrated on low-income countries with generalised HIV epidemics, namely Malawi and Tanzania. Malawi is a small densely-populated land-locked country. Two thirds of its population lives below the national poverty line (17). It is further characterised by rapid population growth, high rates of maternal and child mortality, as well as high levels of malnutrition (47% of children under the age of five are chronically malnourished) (18). The large majority (85%) of Malawians lives in rural areas and relies on subsistence farming for their livelihoods (18). Diminishing plot sizes, depleted soils, erratic rainfall and the high prevalence of HIV, malaria and TB are all of critical concern (18). The country's adult HIV prevalence rate of 10.8% has stabilised with the roll-out of ART, but incidence remains high and adolescent girls appear to be at particularly high risk (14). With a high aid dependency in general and in the HIV response in particular – 98% external financing (19), Malawi's options for domestic financing are more limited, but also urgently needed for the sustainability of the response.

Tanzania was selected for a more detailed analysis in this study, given its economic context and natural gas-related growth prospects, its generalised HIV epidemic and high levels of aid dependence (15, 20). It has an agriculture-driven economy, and about a third of those employed live below the poverty line, indicating low productivity and a lack of decent work (21). HIV/AIDS, malaria and tuberculosis, and increasingly non-communicable diseases, contribute to an average life expectancy at birth of 61 years, with high rates of infant, child and maternal mortality (20). Malnutrition is the single biggest contributor to child mortality, with about 35% stunting among under-fives (20). Although primary school attendance is high (just over 80%), attendance drops dramatically to below 25% for secondary school (22). An estimated 5% of adults are living with HIV, or 1.6 million Tanzanians (21). However, only half of those in need of HIV services are being reached (21). The last multi-sectoral Public Expenditure Review reported that 97% of actual spending on HIV was financed by development partners, mostly

off-budget (23). The financial sustainability of the national HIV programme, and in particular the treatment programme component that claimed 59% of total spending, is a serious concern (23).

3.3 Conceptual framework

The conceptual framework adopted in this research is a combination of a sector-specific resource allocation framework, and a multiple objective, cross-sectoral approach to allocative efficiency. This section starts by providing a typology of the interventions and investments being considered, followed by a description of the economic concepts underlying the proposed approach to financing and economic evaluation. The premise is that cross-sectoral and cross-budget investments could lead to a more efficient allocation of resources as they could enable (i) positive externalities to be internalised, thereby minimising welfare loss; (ii) systemic constraints in the health sector to be addressed and generate the complementary inputs required to deliver HIV services; and (iii) complementary HIV and non-HIV service outputs to be produced and used to optimise individual health production functions.

3.3.1 Intervention typology

There are different types of structural interventions with multi-sectoral benefits that reflect distinct financing decision frames. As depicted in

Figure 3.1, interventions with both HIV and non-HIV impacts can be grouped into three categories, based on what their primary objectives are, and how they relate to basic HIV programme activities. While the latter include biomedical and behavioural interventions that directly impact on HIV transmission, morbidity or mortality, other intervention components could indirectly contribute to these outcomes, either as part of HIV service packages or in combination with non-HIV services (24, 25). Interventions that are delivered within HIV service platforms are likely to be assessed and financed differently than interventions delivered through non-HIV implementers in broader development programmes. In this conceptualisation, it is assumed that each payer has one sector-specific objective, and optimises its resources to maximise the achievement of this objective.

The first category includes structural intervention components that are added on to existing HIV programmatic platforms (HIV+) to address structural barriers and thereby enhance the effectiveness of the basic HIV programme. An example would be transformative community mobilisation and empowerment activities for female sex workers, which would be included in the HIV programme for this population group, in order to prevent their exposure to violence and criminalisation, and enable them to adopt protective behaviours (26, 27). If such an intervention demonstrates an incremental effect over and above the basic HIV programme, it would be

viewed as being within the remit of the HIV budget, and evaluated against other potential uses of HIV resources.

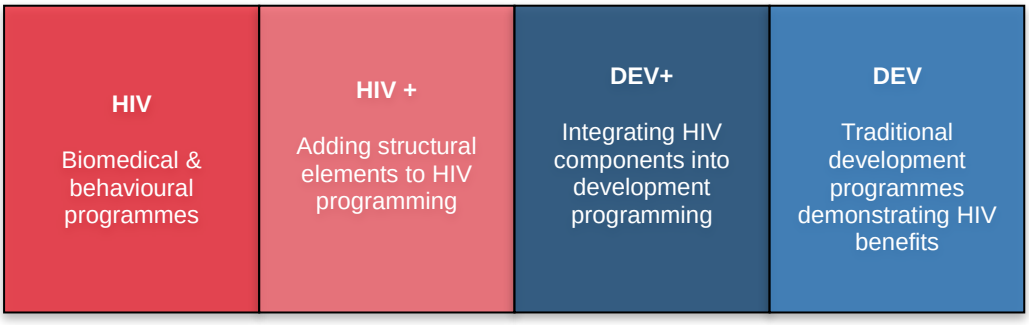
The second category comprises HIV-specific intervention components that are added on to development programmatic platforms (DEV+), such as an HIV and gender training component for microfinance beneficiaries (28). Similarly to the HIV+ category, the incremental costs of these interventions would most likely have to be funded by the HIV budget.

That being said, many of these add-on components that address structural drivers have multiple objectives, in addition to HIV prevention or treatment. Indeed, both HIV+ and DEV+ components tend to involve multi-sector activities that aim to achieve multi-sectoral outcomes. For example, there are several promising integrated models for HIV and intimate partner violence (IPV) prevention (29, 30). In Uganda, a model that combined standard of care HIV services with a community mobilisation intervention to change IPV social norms and behaviours, and a screening and brief intervention to promote safe HIV disclosure and risk reduction in women, reported significant reductions in HIV incidence and past-year experience of physical IPV (29).

Based on this incremental effectiveness, the HIV payer could decide whether to fund the intervention costs, by comparing its incremental cost-effectiveness to other HIV intervention options. If it is more cost-effective than the payer's alternative, it could be sufficient to evaluate it within this single-outcome decision frame, as this would still lead to an efficiency-enhancing financing decision. However, if it is not cost-effective from this perspective, another approach may be required. Since both outcomes are intrinsically valued as the primary goals of multiple payers, the funding decision would need to consider these different payers and their alternative investments to achieve those same outcomes. This is where cross-sectoral economic evaluation and financing approaches will be important.

Some DEV+ interventions could also take the form of strategies to leverage new entry points for providing HIV prevention, care and support services, in light of health system constraints. Using non-health system entry points to target specific populations is not new in health promotion: schools have often been used to reach children with various health campaigns and interventions, such as sexual education, de-worming, vitamin A supplementation, immunisation and mass drug distribution, for example (31). It has been less common for clinical services to be provided outside the health system, because these have more asset specificity (requiring specialised medical labour inputs and equipment), but even for non-clinical services, the HIV response has more often created new structures for its services, as evidence by the mushrooming of community-based HIV organisations in many affected countries (32). However, efforts are increasingly being made to integrate other services into existing HIV structures (33). Again, for such integrated activities and investments to be adequately evaluated from an economic perspective, their multiple financing streams would need to be acknowledged.

Figure 3.1 Typology of structural HIV interventions with multi-sectoral benefits and payers



Source: Author

The third category of structural HIV interventions would be a development programme without HIV-specific components, but with demonstrated HIV impact (DEV). This could be expanded secondary schooling, cash transfers or other social protection interventions for poor and vulnerable households (34, 35). It could also be a horizontal health system strengthening intervention, such as basic training of health professionals and infrastructure development, with downstream benefits for the HIV programme.

The financing decision frame for these interventions may require some form of cost-sharing between the HIV budget and the budgets of other benefitting (sub-)sectors, if they are not fully funded or implemented at scale by the primary implementing sector. This could involve cross-sectoral transfers of resources *ex ante* through reallocation of the overall budget between sectors, or transfers through a co-financing mechanism *ex post*.

3.3.2 Internalising Positive Externalities of Investments

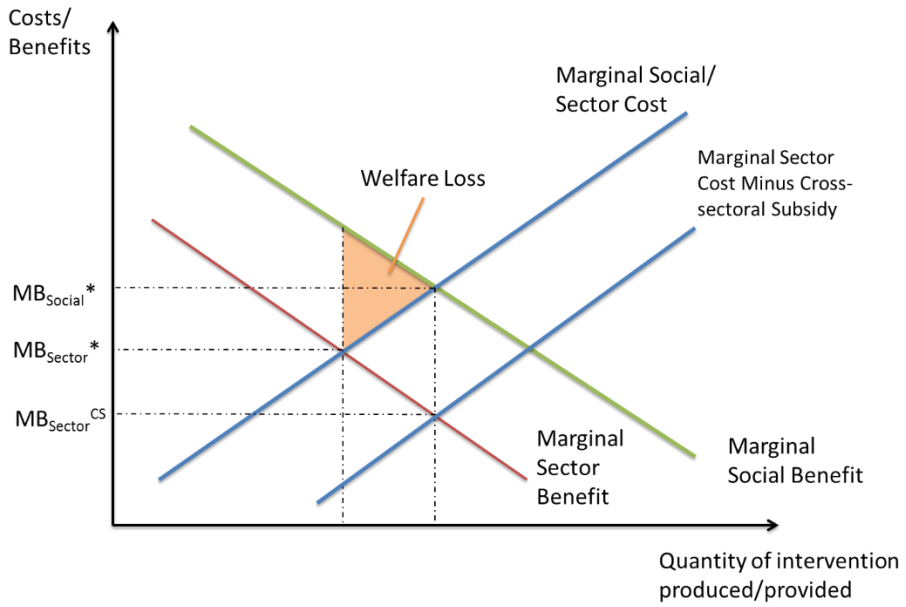
Neoclassical economic theory assumes that through the price mechanism, the market will lead to the most efficient allocation of resources, except when there is a market failure (36). Externalities are one such market failure that occur when certain costs or benefits are not borne by or do not accrue to the individual that decides how much of a good to consume (37). Typical examples of positive externalities are education or immunisation, where the marginal private benefit accrued to an individual is inferior to the potential marginal social benefit from that specific individual investing in her/his education or getting immunised. Therefore, the market is likely to lead to the under-consumption of goods with positive externalities – known as a welfare loss (36). The opposite is true for goods and services with negative externalities, which would be overconsumed or overproduced in a market economy.

The theory can be extended to nonmarket or government failure and is known as ‘derived externalities’ (see Figure 3.2) (38). Silo budgeting and parallel or externally-determined funding

channels generate a situation in which sector-specific budget holders may undervalue investments with multi-sectoral outcomes, even though they have higher marginal social benefits. Such a systemic problem limits the ability of a government to implement an efficient solution.

The conventional solution to externalities is to internalise them through government intervention, either with Pigouvian taxation (for negative externalities) or corrective subsidisation (for positive externalities) (37). It is also argued that if an externality can be traded (implying property rights) and there are no transaction costs, bargaining can lead to an efficient allocation – known as the Coase theorem (39). Although these approaches are not directly replicable for public resource allocations and public service production, central government could increase its allocation to a sector line ministry to stimulate higher production of a specific intervention with broader social benefits; or allow for a cross-sectoral transfer to be used as a mechanism to correct for this allocative inefficiency. Other sectors would effectively subsidise the implementing sector for the amount of MB_{Social}* - MB_{Sector}^{CS}, enabling a socially optimal level of service delivery.

Figure 3.2 Derived positive externalities



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3.3.3 Efficiency gains from investing in complementary inputs

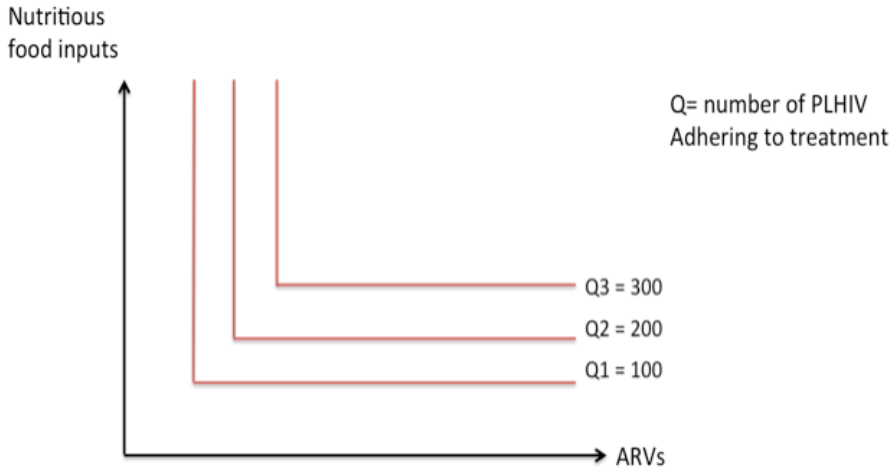
Another way to think about such cross-sectoral transfers is as investments in complementary production inputs to optimise the production of health outputs and health gain. In microeconomic theory, production functions are characterised by a combination of complementary inputs that are used to produce a final good or service (36). In terms of HIV

service production, antiretroviral drugs (ARVs) and nurses function as complementary inputs required to provide antiretroviral treatment and care to a person living with HIV (PLHIV), for example, whereas other inputs can be substitutes (such as nurses and doctors; or a clinic and a mobile truck offering testing and counselling). The unavailability or low quality of one complementary input can act as a binding constraint on the optimal production of HIV services.

Put differently, increased financing to increase the supply of one complement, *ceteris paribus*, may not necessarily increase the level of output. In this case, this investment would be an inefficiency and a form of waste, from an economic perspective. However, in the long run, complements may become substitutes for each other, as technology changes, and even in the short run, there is likely to be some degree of substitution between imperfect complements, depending on the malleability of capital and adaptability of labour (40-42). With imperfect complements, continued investment in one HIV-specific input is likely to have very low marginal returns, whereas partly redirecting such investments to the complement could yield higher marginal returns.

Just as supply-side input levels can constrain HIV service coverage and thus the absorptive capacity of HIV financing, demand-side constraints and social factors could further constrain the efficiency of HIV investments, since these also function as enabling complements. The provision of ART care to PLHIV may not translate into effective treatment outcomes and reduced morbidity and mortality if it is not combined with other complements to enable retention in care and adherence, such as non-stigmatising social norms, or nutritious food (see Figure 3.3). Efficiency gains could therefore be sought by achieving the right mix of outputs required from different sectoral service providers, to produce ultimate HIV outcomes.

Figure 3.3 Perfect complements



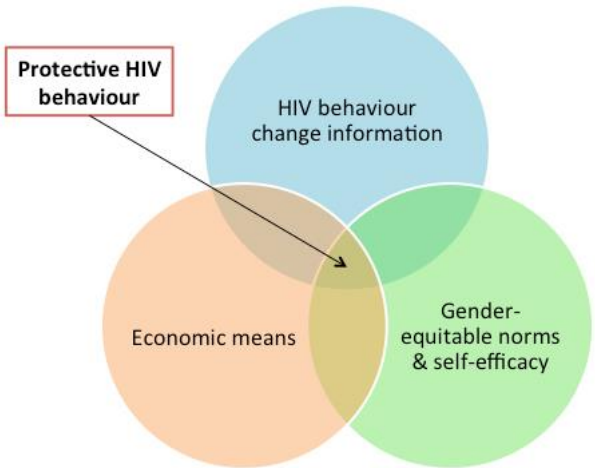
Source: Author

This demand-side conceptualisation also relates to the Grossman health production model, in which health is both demanded and produced by consumers (43). The model defines health as a durable capital stock that an individual inherits at birth and that depreciates with age. Individuals can invest in their health stock through their consumption of health care and other health-promoting or health-damaging commodities. Health care is therefore one input in the individual or household's health production function, along with education and time spent on market and non-market activities, among others.

The example of the combined microfinance and gender/HIV training intervention (IMAGE) illustrates the synergistic effects of complementary service outputs, or individual health production inputs. Indeed, findings from a cluster randomised controlled trial of this intervention model in rural South Africa suggested that the HIV-related outcome of reduced intimate partner violence, as well as increased reported condom use, partner communication and uptake of HIV testing, were achieved through a combination of enabling factors, namely economic empowerment (income effect); gender-equitable attitudes (self-efficacy effect); and HIV information (knowledge effect) (28, 44, 45).

In practice, each of these is an output targeted by separate programmes implemented in different sectors. The HIV outcome may be maximised where these outputs are simultaneously achieved among the same individuals or communities (see Figure 3.4). In some settings with low levels of poverty and with gender-equitable norms, the only intervention required may be an HIV information-education-communication campaign, while in others there may be need for distinct or combined interventions.

Figure 3.4 Example of complementary outputs to generate HIV outcomes



Source: Author

There are two options to realise these efficiency gains and maximise the area of overlap. The first would be to increase public spending in other non-HIV areas simultaneously through re-prioritisation of livelihood programmes and gender-transformative programmes in the national

budget (or reduce wasteful spending on HIV until other sector complements are being invested in – minimising inputs for given output). The second option would be to ensure that spending in those non-HIV areas is HIV-optimal and the existing beneficiaries of those programmes are the ones targeted with HIV-specific intervention components, like behaviour change (maximising output for given input). By overlaying services in this way, both complements are generated and present to produce the outcome of interest. The potential for efficiency gains will depend on the impact of interventions in other sectors on HIV outcomes (partly reflecting the strength of relationship between social determinants and HIV incidence, service uptake and adherence); and the unused capacity in the other sector that could absorb additional resources.

3.4 Development of Methodological Cross-sectoral Co-financing Approach

Design

To meet the first objective of developing a methodological approach for factoring in non-HIV benefits and non-HIV payers in the decision rules of HIV resource allocation, an initial review of the literature was conducted on various health and HIV economic evaluation and resource allocation approaches, as well as prevailing decision rules. As summarised in Chapter 2, the review revealed that investment decisions for HIV are conventionally informed by cost-effectiveness analyses (CEA), while cost-benefit analysis (CBA) are rarely used, which could potentially result in sub-optimal investment choices for interventions with multiple forms of benefit (46-52). However, an alternative decision approach has been proposed by Claxton et al (53) to overcome the challenge posed by such interventions, where CBA is not feasible. This work was used as a theoretical starting point. Since the authors had provided a theoretical and mathematical proof of the multiple objective and multiple constraint optimisation problem at hand, and demonstrated how decision rules based on hypothetical cross-sectoral compensation could provide a second-best solution to the mathematical programming problem, the required extension to this methodology was for an adaptation that would overcome the limitation of ascribing non-health objectives to health payers, as well as an empirical application of the method to the evaluation of an existing intervention.

The approach was adapted to use CEA-based thresholds for actual, not hypothetical, compensation through a co-financing mechanism if the sum of each sector's WTP for its specific benefits was greater than the intervention's cost, but no single sector was willing to pay the full implementation cost. By building in the need for actual cross-budget transfers, the proposed approach is less prescriptive and demanding of what the health payer *should* value in its decision-making, beyond health gain.

To test this approach, its financing outcome was compared to the outcome from a socially optimal CBA approach and the status quo silo CEA approach, estimating the welfare loss from

each outcome, as compared to the net benefit estimated from the CBA. Under this study component, three options were further explored for determining the HIV share in the co-financing scenario, recognising the different evaluative spaces and economic evaluation tools used by different payers and sectors and the potential of payers to game with their WTP and possibly free-ride, if others are willing to cover the costs of the intervention (54).

From this proof-of-concept, it became clear that the decision rules and estimation or elicitation of cost-effectiveness thresholds was critical and needed further theoretical elaboration in the context of new health economic evaluation guidance that called for disaggregated societal perspectives, without specifications on how non-health consequences were to be valued (55, 56), and the emerging debate around what WTP thresholds represent: a supply-side measure of marginal productivity, or a demand-side measure of the consumption value of health (57-60). Taking the decision-maker's perspective and the view that WTP thresholds are cost-effectiveness thresholds that measure the opportunity cost to a health payer of investing in an intervention, the co-financing approach required further elaboration and framing of these measures from a multi-sectoral perspective, rather than the standard unisectoral approach. Since the objective was to provide a proof-of-concept, a stylised two-sector model was developed and used to illustrate the potential losses to the health and education sectors from not considering a co-financing mechanism – or cross-sectoral transfer, when conceptualising and measuring their respective cost-effectiveness thresholds.

Data sources

To illustrate this theoretical co-financing approach and assess its potential to generate efficiency gains, a case study was used of a cash transfer trial in Malawi. Published secondary cost and outcome data were collected from this cluster randomised controlled trial implemented by the World Bank from January 2008 to December 2009 (61). All never-married girls aged 13-22 in a random sample of 176 enumeration areas in the rural district of Zomba were invited to take part in the trial. Of these, 3,796 were enrolled at baseline, with 1,225 randomised to the treatment group and offered monthly cash transfers. The majority (789) were already in school at baseline while the others had dropped out of school (436). Among the baseline schoolgirls, 506 were randomised to a conditional arm, whereby their receipt of the monthly cash transfer was dependent on their 80% school attendance. The unconditional arm received the cash regardless of attendance.

The results of the trial were reported in several reports and academic papers, with evidence of statistically significant impacts on prevalent HIV, prevalent HSV-2, school enrolment, English test scores, school drop-out rates, pregnancy rates and depression (61-64). The costing of the intervention was a financial costing from the provider's perspective, and was sourced directly from the authors both for the trial scenario and a hypothetical scale-up scenario, which assumed lower administrative costs (25, 65).

Data analysis

In the case study, three financing approaches were modelled. In the first approach, HIV and non-HIV budget holders participated in a cross-sectoral CBA and funded the intervention if the benefits outweighed the costs. In the second silo approach, each budget holder considered the cost-effectiveness of the intervention in terms of their own objectives, and funded the intervention if its cost per sector-specific unit of outcome was below the sector-specific WTP threshold. In the third co-financing approach, budget holders used CEA to determine how much they would be willing to contribute towards the intervention, provided that other sectors were willing to pay for the remaining costs.

To estimate how much each sector would be willing to pay for the intervention, the first step was to determine which (sub-)sectors would have a vested interest in the intervention. Given its benefits, the HIV budget holder, the sexual and reproductive health budget holder, the mental health budget holder and the education budget holder were considered as potential payers. The health budget was divided into sub-budgets to reflect the reality of multiple funding streams for different health programmes. In particular, the HIV budget is quite distinct and heavily donor-funded, which is why it was analysed separately from the health budget that would cover other sexual and reproductive health programmes and mental health (60, 66). Trial outcomes were modelled through to what each payer's primary outcome measure(s) was expected to be. For example, all health outcomes were modelled through to DALYs using standard formulae.

The maximum contribution each (sub-)sector would be willing to make towards the intervention was then calculated as the impact per sector multiplied by its WTP threshold for that outcome unit. For example, for health outcomes, the maximum contribution was the number of DALYs averted multiplied by GDP per capita – the normative WHO WTP threshold at the time (67). However, since no established normative cost-effectiveness thresholds were identified for the education sector, the highest incremental cost-effectiveness ratio (ICER) per education outcome found in previous economic evaluations in sub-Saharan Africa was used as a positive or revealed threshold (68-71). All the ICERs were adjusted to 2009 USD using the United States inflation rates and adjusted to Malawi using the ratio of the ICER to the 2009 GDP per capita of the country in which the intervention was implemented (72).

In the methodological case on the importance of taking a multi-sectoral perspective when conceptualising cost-effectiveness thresholds (CET) as decision rules, the analysis drew on Culyer's bookshelf metaphor that illustrates efficient health budget priority-setting of ranking health interventions by their productivity and funding the most efficient ones until the budget is exhausted (57). In this case, the ICER of the last funded intervention is the CET of the health budget. Whereas Culyer's bookshelf only considers a single health outcome, the multi-sectoral extension proposed also considers another 'education' bookshelf, and explores with stylised examples how an intervention with both education and health benefits may be undervalued in

each bookshelf, and how this would change if cross-sectoral co-financing were possible and the costs borne by each sector reduced.

3.5 Adaptation of Fiscal Space Analysis

Design

To explore the potential of creating fiscal space for HIV across sub-Saharan Africa, by incorporating the value of co-financing for investments in health system strengthening and broader development programmes, and ascertain how this would compare to traditional fiscal levers, this study component drew on a combination of the basic fiscal space framework, a health systems constraints framework and the concept of cross-sectoral co-financing developed under the first objective of this research.

Figure 3.5 summarises the specific conceptual framework adopted. Fiscal space is conceptualised as additional funding that can be secured from various sources for the achievement of a specific objective, in this case reduced HIV morbidity and mortality. As illustrated in the left part of the figure, total government expenditure is a function of total revenues and interest payments on previous borrowing (73):

$$G_t = f\,(T_t,\ B_t,\ E_t,\ O_t,\ r_t B_{t-1})$$

Where G_t is government non-interest expenditure in time t; T_t is taxes, fees, and other government revenues, including those arising from seigniorage (inflationary finance); B_t is total government borrowing (domestic and foreign, net of use of deposits); E_t is external grants; O_t is other sources of funds, such as sale of assets; and $r_t B_{t-1}$ is non-discretionary debt interest payments. Increasing the various sources of revenue could therefore increase the fiscal space for HIV, *ceteris paribus*.

At its minimum, sector-specific fiscal space for the health sector, for example, is a fraction (k) of total government expenditures ($H_t = k\ G_t$). Much of the focus of fiscal space analyses has been on maximising total revenues, sector-specific revenues (through earmarked grants or taxes for example) and the relative allocation of the budget. This conceptual framework considers that beyond these sources, further fiscal space could be generated for HIV by investments in other sector interventions that contribute to HIV outcomes, but are not accounted for as HIV-related investments, as depicted by the shaded red arrows in Figure 3.5.

Based on the concept that health outcomes result from various social, economic and environmental factors, in addition to health care delivery (74), we consider that fiscal space for HIV - or government expenditures that contribute to HIV outcomes – is likely to include an HIV-

specific budget as well as a fraction of health system expenditures (HS) and expenditures in other socio-economic sectors (SE):

$$HIV_{FSt} = HIV_t + ß\ H_t + \mu\ SE_t$$

Rather than focus on the HIV budgetary expenditures alone, the approach taken incorporates these HIV-allocable fractions in other sectors and consider how the HIV-specific budget (HIV_t) could be used to crowd these in and fully leverage them, as depicted by the unshaded red arrows in Figure 3.5.

For our study, this required investigating the relationship between fiscal policies, health system constraints and demand-side socio-economic factors, and public HIV financing. The three questions of interest were: (i) do health system constraints and poor socio-economic factors limit the production of HIV service outputs?; (ii) If so, what is the economic value to the HIV programme of more effective public investments in addressing these binding constraints?; and finally, (iii) how does this efficiency gain from non-HIV investments compare to traditional sources of fiscal space?

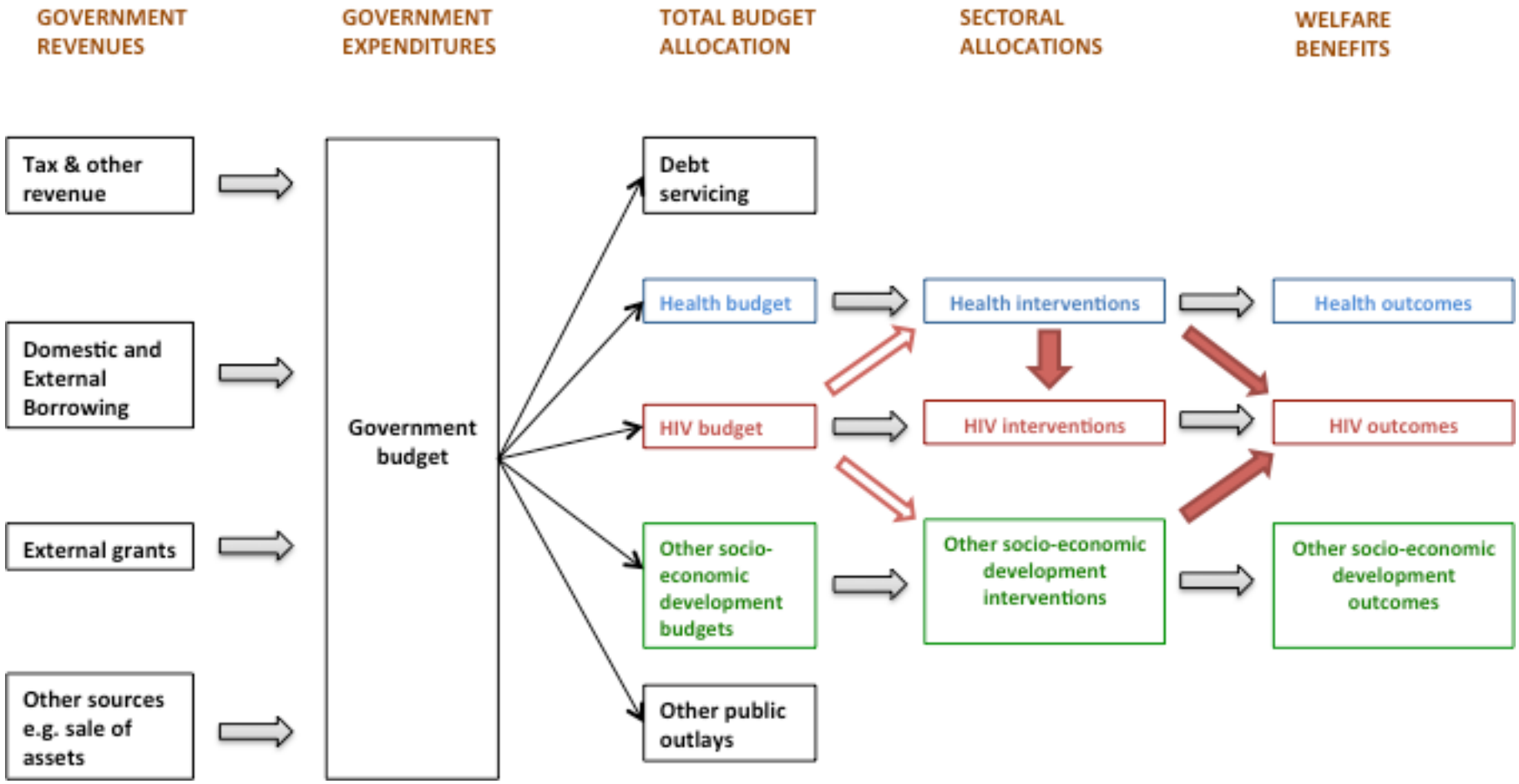
To examine the influence of health system and development factors on fiscal space for HIV, an econometric analysis was conducted with a global cross-sectional dataset. Past public HIV spending was selected as a proxy measure of fiscal space, and a cross-sectional design was adopted in the absence of panel data for this primary variable (75).

First, a 'fiscal' model was specified to explore the extent to which different fiscal space sources had been effectively tapped to generate additional public resources for HIV programmes. Next, a second HIV service 'coverage' model was specified to examine whether and how much improved health system performance and social sector outcomes would result in efficiency gains in HIV service coverage. The models were then used to quantify the potential fiscal space from various sources using a peer approach for 14 selected SSA countries (76). The potential increase of a specific source of financing to a normative threshold or mean/median by income category was entered into the estimated model for each country to compute the potential increase in spending. For the health system and non-health factors, efficiency gains were estimated as the increase in spending that would be required to reach the same level of HIV service coverage, as would be achieved if non-HIV normative targets were met through effective investments in other sectors.

Data sources

Most recent publicly available global data between 2008 and 2012 was collected from reliable online databases, namely the World Bank's World Development Indicators, UNAIDS Aidsinfo, the WHO Global Health Expenditures Database, the IMF country reports on macroeconomic and fiscal performance, the UNESCO education statistics, the UN population statistics and the OECD-DAC/CRS database on aid disbursements.

Figure 3.5 Sector-specific Fiscal Space Framework with Cross-sectoral Spill overs



Source: Author

Data analysis

For HIV service coverage, the theoretical model was a standard economic Cobb-Douglas production function for the technological relationship between HIV programme output and factor inputs (77), namely:

$$Y = A\, L^{\beta}\, K^{\alpha}$$

Where Y is total HIV service outputs (production), L is labour inputs (health personnel), K is capital input (HIV spending), A is total factor productivity, and α and β are the output elasticities of capital and labour.

To illustrate the co-financing method, the analysis focused on the production of Prevention of Mother-to-Child Transmission (PMTCT) screening services, using selected HIV-specific and non-HIV inputs. These choices were largely driven by data availability, as well as the health system constraints framework developed by Hanson et al (78). The latter describes the constraints of scaling up priority health interventions and distinguishes between five levels of constraints, starting with the community and household level (i.e. the demand side), followed by a health service delivery level and a health sector governance level of constraints (i.e. the supply side); and finally broader public sector and environmental levels of constraints. Ranson et al use this framework to develop a typology of countries, using empirical data (79). The analysis built on the indicators they selected to include for each level of constraint, as well as previous work on health worker density and health service coverage (80), to construct the model.

At the service delivery level, there are several inputs that interact as complements. It is therefore clear that if the HIV budget holder only allocates resources to supply ARVs to heath facilities, without investing in the complementary human or physical resources at the point of service, the latter will limit the number of services effectively provided. With an increasing reliance on provider-initiated HIV testing and counselling and the importance of antenatal care services as an entry point into ART and PMTCT services, it is clear that the demand and therefore scale up of core HIV services depends on the capacity of other health services in the health system. There is evidence that the availability of qualified medical personnel is particularly critical for effective maternal health services and outcomes (81, 82). A measure of health worker density was therefore selected as a non-HIV policy lever that could enable increased HIV (PMTCT) programme efficiency, among others. The other two non-HIV areas of investment explored were female education and food insecurity, given their expected and identified role in the uptake of maternal health and PMTCT services (83).

In the specified model, the dependent variable was PMTCT screening coverage, namely the proportion of pregnant women tested for HIV (from the UNAIDS Aidsinfo database). The

explanatory variables of interest were financial HIV inputs (total HIV spending per PLHIV) and human resource inputs (nurse density). Demand-side inputs or constraints were also considered, namely female education (adult female literacy) and food insecurity (proportion of people malnourished in the total population) (78, 80). Additionally, we controlled for GDP per capita (84), disease burden (adult HIV prevalence), and environmental factors that may affect accessibility and efficiency, namely urbanisation rate and governance (control of corruption) (78, 79).

All independent variables were transformed into natural logarithms in the estimated regression equation, in line with the exponential Cobb-Douglas function. Since the dependent variable was bounded (0-100 %), a generalised linear model was used, with logit link function (85) and the binomial family. The censored Tobit model was also used to test the robustness of the linear approximation.

Besides the specification issues, one major limitation of this model was the use of total HIV spending instead of PMTCT spending, due to data availability. The latter would have been a more accurate reflection of the production function. However, if a relatively constant proportion of PMTCT spending in total spending is assumed, the modelled relationship would still hold.

In terms of PMTCT screening, one could think of HIV testing kits (captured by HIV spending) and nurses being complementary inputs required to provide screening services to pregnant women (80). Based on this, the analysis considered that increasing one of the HIV or non-HIV inputs in the production function could increase HIV service production, as suggested by the model. Thus, the model was used to estimate how much more PMTCT screening coverage could be achieved if countries were to reach the WHO minimum norm of having 2.3 health workers per 1000 population (86), and then to estimate how much more a country would have had to spend from the HIV budget to achieve that same increase – as a measure of potential HIV budget saving (see Appendix 2, Table S14). In economic terms, the rate of technical substitution between labour and financial inputs was calculated, to get to a monetary valuation of reaching the norm of health worker density, for the HIV budget constraint (87). This monetary value is equivalent to the extra HIV spending that would be required to reach the same level of PMTCT screening coverage (a proxy of HIV service outputs), as would have been achieved from increasing the number of health workers to the norm (through another budget). That percentage increase in total spending was then applied to the public HIV spending figure.

Similarly, a reduction in undernourishment to the MDG target of 11.7% (half of 1990 level in developing countries of 23.4%)(88) was applied to explore how this could produce HIV pay-offs in terms of increased PMTCT screening coverage. The same approach was used to estimate how much extra HIV spending would have been required to get the same increase (see Appendix 2, Table S15). The details of the mathematical formulas are presented in Appendix 2, section 6.

3.6 Application of Co-financing Analysis for Food Assistance Intervention

Design

To delve deeper into the potential of co-financing analysis as an economic evaluation method, a specific structural HIV intervention was selected as an application case study. The intervention was a 6-month food assistance intervention for food-insecure people initiating ART. Primary cost data and secondary outcome data were collected from a trial in Tanzania (89, 90). Using these data and complementary regional data, national co-financing scenarios were analysed to assess the cost-effectiveness for the HIV programme, the HIV budget impact and affordability of a scaled-up national co-financed programme in five high burden countries in SSA: Tanzania, Zambia, Ethiopia, Lesotho and South Africa. These countries were selected purposively to reflect a mix of profiles, in terms of HIV burden, income and food insecurity levels.

A Markov model was developed to estimate the costs and outcomes of providing food assistance to these patients during their first 6 months on ART, compared to a 'standard of care' base case. The analysis adopted both a health care provider perspective, and a broader multi-sectoral perspective to capture the non-health consequences of the intervention following a co-financing approach. The latter involved modelling a scenario in which the HIV outcomes and potential food security outcomes of the intervention were taken into account, and valued by an HIV payer and food security or social protection payer, respectively. The primary model outcomes were a cost per Disability-Adjusted Life Year (DALY) averted, and a benefit-cost ratio (BCR). The time horizon of the study was the lifetime of the cohort of patients initiating ART.

The Afya study in Tanzania

Both the HIV impact and cost data were sourced from the Afya study (89) - an individually randomised controlled trial conducted by the University of California, Berkeley and the Ministry of Health & Social Welfare in the Shinyanga region in Tanzania (89). It assessed three delivery models for short-term food and nutrition support for PLHIV: nutrition assessment and counselling (NAC) alone (the standard of care); NAC plus cash transfers; and NAC plus food assistance. In the latter group, food-insecure patients received a standard household food ration, including whole maize meal (12 kg), groundnuts (3kg) and beans (3kg), with a financial value of approximately USD 11 per month. The study compared the effect of the combined NAC and food or cash assistance (both arms) versus NAC alone, on retention in care and ART adherence. The intervention was provided from December 2013 to February 2016, with 345 participants enrolled in the food basket arm (90). At 6 months follow-up, both the food basket and cash transfer were found to have significant effects on retention in care and treatment adherence, measured as the proportion of

patients with medication possession ratio ≥95% during the 0-6 month interval (90). These effects were not sustained at 12 months for the food basket arm.

Cost Analysis

An economic costing of the trial was conducted as part of this research, in order to compare the outcome and cost data in a co-financing analysis. A combination of standard step-down and ingredients costing was used to estimate the economic costs of providing the food basket (72). Only the provider intervention costs were considered in this analysis, since the indirect provider costs at the health facility level from increased health service utilisation are included elsewhere in the modelling. Costs incurred by patients, such as transport or foregone productivity, were not included in the analysis, given that they would not be expected to fall on the health care budget (55).

Cost data were collected at the 3 Afya trial sites, namely Shinyanga Regional Hospital, Kahama District Hospital and Kambarage Health Centre, as well as from the research team at the University of California, Berkeley and at the Ministry of Health and Social Welfare. Data was collected in August-September 2015 for the start-up period (1 January 2013 to 30 November 2013) and in March 2016 for the intervention period (1 December 2013 till 29 February 2016).

Costs were categorised as recurrent and capital costs. Capital costs were annuitized using a discount rate of 3%. Input prices were obtained from the project, health facilities and regional office financial records, as well as local suppliers. Costs were estimated in Tanzanian Shillings (TZS) and then converted into 2015 USD, using weighted average annual Bank of Tanzania Interbank Foreign exchange rates, and the United States GDP deflator for costs incurred in 2013 and 2014.

Research costs were excluded in both the start-up and implementation phases. To be conservative, start-up costs were included in full in total intervention costs, as it was not possible to determine whether and which of these costs would yield benefits beyond the duration of the study.

All project overhead and intervention costs were allocated based on estimated use for the following activities: project administration and management; research; client identification; monitoring conditionality; cash transfer; and food basket. Overhead costs were allocated using step-down allocation to support cost centres, and then to the final cost centres, namely the Food basket or the Cash transfer. Staff time allocation between activities was estimated from a combination of self-assessments, interviews and time sheets, and used to allocate overheads. The proportion of beneficiaries receiving food baskets was used to allocate the support costs of client identification and conditionality monitoring. The unit cost was estimated as a cost per patient enrolled to receive the food basket for 6 months.

Co-financing analysis

The co-financing scenario (or 'multi-sectoral perspective') involved modelling the non-health impact of the intervention. However, the evidence base on the broader welfare effects of food assistance (e.g. on labour productivity, nutrition) is scant (91) and only one recent study was identified from Honduras with a demonstrated effect of food assistance on severe food insecurity among established ART patients (92). The implications of this potential effect on food security were explored by modelling what would happen if part of the incremental costs of the intervention were covered by a social protection budget based on this benefit, based on the co-financing approach developed under objective 1. The social protection sector's or payer's revealed WTP per averted case of severe household food insecurity was derived from studies on the cost and impact of a cash transfer programme on severe food insecurity in Zambia (93, 94).

Univariate and probabilistic sensitivity analyses (PSA) were conducted to explore the sensitivity of the results to various parameter and distributional assumptions (see Chapter 7 and Appendix 3).

Based on data from the Spectrum model on the estimated number of people initiating ART per year from 2016 to 2020 in the five countries (95), an estimate of severely food-insecure patients who would be eligible for food assistance was derived and used to model national budget impact, HIV impact (in terms of DALYs averted) and cases of severe food insecurity averted until 2030.

One of the major methodological limitations in this applied co-financing analysis is the use of the cost-effectiveness ratios from implemented non-HIV programmes as a proxy measure of revealed WTP or of the cost-effectiveness threshold of the non-HIV budget constraint. In this case, the cost per household case of severe food insecurity averted through an implemented cash transfer programme was assumed to reflect the alternative investment, or opportunity cost, to the social protection payer. Moreover, it was extrapolated from one programme in Zambia to all remaining countries. For more optimal decisions, the estimation of local sector-specific cost-effectiveness thresholds would be required.

3.7 Qualitative Analysis on Institutional Feasibility

Design

For a better understanding of the institutional feasibility, incentives and disincentives to adopting a co-financing framework in HIV financing and priority-setting, there was a need to gain insights and elicit the perspectives of decision-makers who would actually be the ones to decide whether or not to contribute towards cross-sectoral programmes. In the absence of initiatives to operationalise co-

financing mechanisms in low and middle-income countries, qualitative interviews with decision-makers were considered the most appropriate method for an initial assessment of the acceptability and feasibility of the approach (13).

The theoretical underpinnings of this study component remain rooted in the positivist discipline of health economics, with insights from political economy theories (96). Although there is likely an objective reality of how resources are allocated, it was acknowledged that the interaction between the researcher and the decision-makers would allow for a joint construction, or co-production and interpretation of the institutional feasibility of applying this relatively novel approach to public financing (97). This methodological choice is not without its limitations, given the potential response and desirability bias, which may overplay the institutional feasibility of the approach (13).

To ground the interviews in a national context and reality, deepen the joint analysis and minimise hypothetical discussions, Tanzania was selected as a case study. This study component focused on the Tanzanian national cash transfer programme (TASAF) as a tangible example to explore for co-financing (98), and drew in the two case studies of cash transfer interventions with empirical evidence of multi-sectoral HIV and non-HIV impacts in Tanzania and Malawi (61, 90), analysed under objectives 1 and 3.

The main limitation of this case study approach with qualitative interviews was its context-specific nature and lack of generalisability (10). However, it is also by providing context and localising the potential co-financing decisions in a real-world context that the analysis is most relevant (11). Moreover, many of the international organisations involved in financing health and development programmes in Tanzania are also operating in other LMIC, and their institutional incentive structures are likely to be similar.

Data generation

Data collection started from a rapid mapping of the main payers (budgetary authorities) in Tanzania for a scaled-up cash transfer intervention. Policy-makers were purposively selected on the basis of their positions and involvement in planning and resource allocation, and sector coordination in the HIV, health, social protection and food security sectors. Primary data was then collected using qualitative methods in the form of key informant interviews with 20 policy-makers, programme managers and budget holders at the national level, both in government and among key development partners.

The interview guide explored the principles used in resource allocation and their application to cross-sectoral programmes, as well as the perceived institutional feasibility of a co-financing approach. Specifically, it started by investigating how the planning and priority-setting within the remit of the respondent had been done for the current medium-term plan and annual budgeting

cycle; what criteria were considered; what outcomes/objectives were being optimised; and what constraints each decision-maker faced. Next, a set of questions were designed to determine each sector's opportunity cost, by eliciting decision-maker's willingness-to-pay (WTP) for key sectoral outcomes. Finally, the topic guide re-introduced co-financing with the TASAF example, and evidence of the programme's and other cash transfer interventions' multi-sectoral impacts. It then explored respondents' perceptions on the benefits, risks, barriers, enablers, and potential mechanisms for implementing cross-budget co-financing.

A document review was also conducted in preparation for the interviews to enable more informed discussions around national planning and priority-setting.

Data analysis

The interview transcripts and the researcher's interview and post-interview notes formed the basis for the analysis, while data from the documents reviewed were used to support and validate the issues that emerged. Principles of grounded theory were applied (99). First, the researcher read through all the interviews to identify high-level general themes. Second, each interview transcript and the interview notes were coded using a mixed deductive and inductive approach to identify key concepts and new ideas (100). Third, the data was organised into groups of ideas or categories that were more generalizable. To evaluate the institutional feasibility of co-financing, the analysis considered how these categories related to the assumptions of co-financing, and where they did not, further investigation went into determining to what extent co-financing could be applied within the existing resource allocation processes. The analysis was conducted in NVivo 10.

3.8 Ethics Approvals

Ethical approval for the overall study was sought and obtained from the London School of Hygiene and Tropical Medicine Research Ethics Committee (No. 9600). Additional ethical approval for the study components conducted in Tanzania were sought and obtained from the Tanzanian National Institute of Medical Research (No. NIMR/HQ/R.8a/Vol.IX/1631), the Tanzanian Commission for Science and Technology (No. 2015-180-NA-2015-236) and the Institutional Review Board of the University of California, Berkeley (No. 2013-07-5442).

Study participants were provided with a study information sheet, which included an explanation of the purpose of the study and the terms of the participant's consent. Participation was completely voluntary and formalised by the respondent's signature of a consent form.

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RESEARCH PAPER COVER SHEET

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SECTION A – Student Details

Student	Michelle Jeanette Sayi Remme
Principal Supervisor	Prof Anna Vassall
Thesis Title	Cross-sectoral co-financing: Taking a multi-payer perspective in the financing and economic evaluation of structural HIV interventions

If the Research Paper has previously been published please complete Section B, if not please move to Section C

SECTION B – Paper already published

Where was the work published?	AIDS		
When was the work published?	January 2014		
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion	N/A		
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SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	I was the lead author of this paper and conceptualised it with CW, BL and AV. I designed and conducted the study. JL provided additional support for reviewing some of the literature. I drafted the full manuscript and made revisions based on comments from AV, CW and BL.

Student Signature:  **Date:** 23/10/2017

Supervisor Signature:  **Date:** 29/10/2017

CHAPTER 4 Financing structural interventions: going beyond HIV-only value for money assessments

4.1 Introduction

HIV/AIDS is one of the leading global causes of morbidity and mortality globally (1). Despite substantial successes, high rates of new infections and AIDS deaths persist. Structural factors – including poverty and limited livelihood options, stigma and discrimination, gender inequality and violence, among others – help drive and sustain the epidemic, as well as undermine the effectiveness of proven HIV interventions (2). There is, therefore, renewed interest in interventions that seek to address such factors (2, 3) through an expanding range of structural interventions, both to modify the broader socio-economic environment that shapes HIV risk, as well as to enhance the uptake and effectiveness of core HIV prevention and treatment services (4-6). Although evidence of the effectiveness of these interventions is limited, a few rigorous studies have demonstrated the potential of enhanced microfinance or cash transfer schemes to reduce HIV-related risk factors and ultimately HIV infections, while simultaneously improving other development indicators (7, 8).

The changing HIV funding landscape makes the argument for investments in structural interventions all the more compelling. After a decade of unprecedented investments, external HIV financing is flat-lining, while domestic resources are increasingly expected to sustain and scale up national responses (9-12). This shift is framed as an opportunity for more 'shared global responsibility' and a more prioritised investment approach (13, 14). No longer insulated by earmarked external funding (15), HIV programmes in resource-limited settings will increasingly compete with other health and development priorities for resources. In this context, structural interventions with multiple outcomes could become more attractive. Rather than displacing financing to other sectors, HIV funds that support structural approaches could leverage such resources, catalysing synergistic investments across health and development sectors, as promoted by the HIV investment framework and several other policy agendas and academic works (3, 13, 16-22).

Despite the potential of structural interventions, there is a risk that they will not be prioritised within HIV programme resources, given the perception that they are beyond the remit of the HIV 'sector' (23-25). This concern is compounded by the fact that, conventionally, investment decisions for HIV are expected to be informed by cost-effectiveness analyses (CEA) (26-29). These compare the costs of HIV programmes with their direct HIV outcomes only, such as HIV infections averted or life years saved. CEA typically does not factor in the multitude of health co-factors or co-morbidities that are known to influence the complexity of HIV transmission, nor

does it incorporate complementarities between interventions and positive spill overs (30). The alternative and more comprehensive approach is cost-benefit analysis (CBA), embedded in welfare economics, which is concerned with whether social benefits generated by an intervention outweigh its costs. Both social benefits and costs are measured in monetary units. This approach is very rarely used in HIV priority-setting discussions (31, 32). However, the use of cost-effectiveness rather than cost-benefit analyses could potentially result in sub-optimal investment choices for interventions with multiple forms of benefit (33). In economic terms, this would represent a 'welfare loss'. Current budgeting arrangements further promote this silo approach, as they rarely encourage sectors to explicitly factor in the costs and benefits of their resource allocation decisions to other sectors (34-38).

Given the multiple interactions between HIV outcomes and broader health and development interventions, allocating HIV resources on the basis of HIV cost-effectiveness alone may not be optimal. To investigate this hypothesis, we examine the consequences of alternative approaches to resource allocation and financing, based on a case study. Our analysis seeks more specifically to explore: (i) the extent to which the current approach – using HIV-focussed cost-effectiveness decision rules – could lead to sub-optimal HIV financing decisions; and (ii) whether there may be different ways in which the HIV sector could co-finance structural interventions.

4.2 Methods

Intervention modelled

We used data from the Zomba cash transfer trial in Malawi, which provides proof-of-concept that altering socio-economic contexts can be an effective strategy to prevent HIV. The cash transfer was provided between 2008 and 2009 to 1,225 girls (ages 13-22) and their households, with payments being conditional upon school attendance for a sub-sample of 506 girls. At 18 months follow-up, HIV prevalence among schoolgirls in the intervention and control groups was compared, suggesting an adjusted reduction in prevalent HIV of 64% among those who were already in school at baseline (Adjusted Odds Ratio= 0.36, 95% CI 0.14–0.91) (7). Additionally, significant reductions in prevalent Herpes Simplex Virus type 2 (HSV-2), school drop-out, teen pregnancy and depression were observed, as well as improvements in school enrolment, attendance and English test scores (7, 39-41).

Estimating impact and costs

Although we did not aim to conduct a detailed economic evaluation of this intervention, we nevertheless needed to estimate its costs and impacts to illustrate the different financing approaches. The incremental impact for key indicators was calculated from the post-trial difference between intervention and control groups, multiplied by the number of girls in the

impacted (sub-)group. We then translated the units of health outcomes into Disability-Adjusted Life Years (DALYs) averted, using standard formulae for HIV and estimates from the literature for the other health outcomes (see Appendix 1). Baird and colleagues estimated that in a non-trial setting and at scale the intervention could be implemented at an incremental financial provider cost of USD 90 per beneficiary (7, 42). All costs were adjusted to 2009 USD.

Different approaches to deciding whether to finance the intervention

We compared the application of three approaches for deciding whether to finance a structural intervention to keep adolescent girls in school. In the first approach, HIV and non-HIV budget holders conduct a joint *cross-sectoral CBA* and fund the intervention if the benefits outweigh the costs. This should lead to the most efficient allocation across sectors. In the second *silo approach*, each budget holder considers the cost-effectiveness of the intervention in terms of their own objectives and funds the intervention based on their sector-specific thresholds of what is cost-effective or not. In the third *co-financing approach*, budget holders use CEA to determine how much they would be willing to contribute towards the intervention, assuming that other sectors cover the remaining implementation costs. In detail:

1. *Cross-sectoral CBA*

In the CBA approach, the decision rule is simple: investing in an intervention with a net benefit is efficient. In addition to HIV benefits, education and other health benefits were included and converted into monetary units. To estimate these, we used long-term benefit-to-cost ratios found in the literature on conditional cash transfers for school girls in developing countries (43). These estimate a range from 3.5 to 26 of benefits to costs achieved through increased future earnings and reduced future child mortality (43). HIV benefits were monetised by valuing HIV DALYs at USD 1,000 (in line with the other health benefits) (44) and discounted lifetime costs of antiretroviral therapy (ART) from South Africa (45) were partly adjusted to estimate cost savings from each HIV infection averted.

2. *Silo approach*

The silo approach requires the use of incremental cost-effectiveness ratios (ICERs). These are estimated when an intervention costs and achieves more than the status quo - as the ratio of the additional costs to the additional benefit. The decision rule is then based on comparing this ICER to a standard cost-effectiveness threshold, or willingness to pay (WTP), per HIV outcome (46). The World Health Organisation (WHO) has set this WTP threshold at a cost per DALY averted below Gross Domestic Product (GDP) per capita (47-49). This is primarily derived from a human capital approach, whereby a year of life is valued as an individual's economic productivity (50). While there are a range of other approaches (46), the WHO benchmark was taken as it is commonly used in economic evaluations of HIV interventions (29, 51, 52).

For the case study, the maximum contribution each (sub-)sector would be willing to make towards the intervention was calculated as the impact per sector multiplied by its WTP threshold for that outcome unit. For example, for health outcomes the maximum contribution was the number of DALYs averted multiplied by GDP per capita (WHO threshold). Since we did not find established cost-effectiveness thresholds in education (53-56), the highest ICER per education outcome found in previous economic evaluations in sub-Saharan Africa (57) was used as the threshold.

As illustrated in Figure 4.1, the HIV budget holder would fully fund intervention A, which averts a quantity Q_A of HIV-related DALYs at a total cost of C_A, and therefore has an ICER below the threshold (R_T). Conversely, the ICER of intervention B is above the threshold, meaning that, from an HIV perspective, B would not be considered for investment.

3. Co-financing approach

Claxton and colleagues propose an alternative decision approach to overcome the challenge posed by interventions with cross-sectoral costs and impacts, where CBA is not feasible – coined the 'compensation test' (36). If other sectors can compensate the implementing sector for its surplus (or net) cost (i.e. the cost over and above the value of the benefits to the implementer), then the intervention should be funded. Our approach is slightly different in that we propose to use CEA-based thresholds and to have actual, not hypothetical, compensation through a co-financing mechanism if the sum of each sector's WTP for its specific benefits is greater than the intervention's cost, but no single sector is willing to pay the full implementation cost. Whereas CBA approaches tend to capture multiple long-term economic benefits, the CEA-based approaches often relate more to immediate intervention outcomes (58), which is likely to be closer to financing decisions in practice. Similar to intervention B in Figure 4.1, this would amount to the HIV sector financing up to C_T, as long as other sectors contribute C_B-C_T to enable implementation.

Welfare loss

We then compare the silo and co-financing approaches by estimating the welfare loss in relation to the allocation obtained under the optimal cross-sectoral CBA approach. This was estimated as the net benefit foregone by not implementing an efficient intervention. The assumption is that the alternative use of resources for each sector is to do nothing.

Approaches to determine the HIV share

In principle, the share the HIV sector could be willing to pay would be equivalent to its threshold (*maximum* WTP). However, in cases where benefits substantially outweigh costs, it may be possible to invest less HIV funds. In this case, the HIV sector could establish its *minimum* WTP as the residual amount that other sectors would not cover, i.e. total costs minus the sum of other sectors' WTP, as long as this is below C_T.

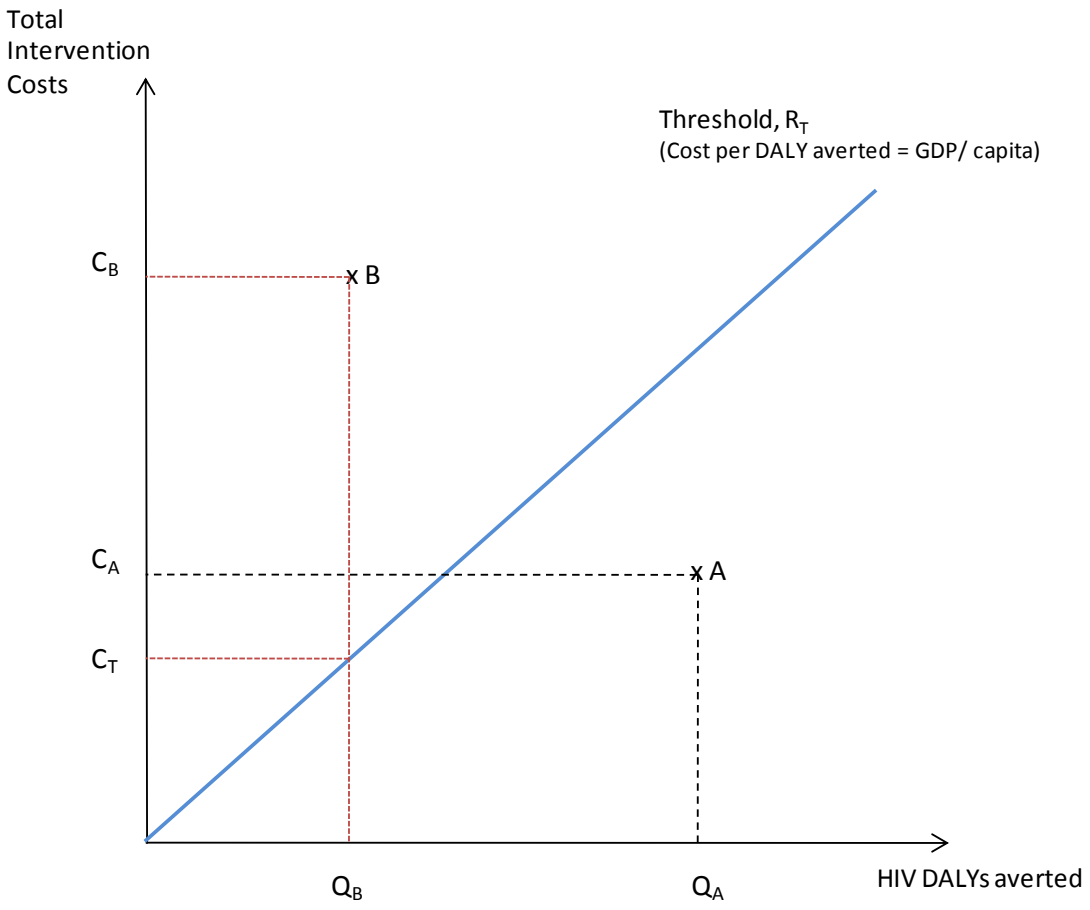
Another approach would be for the HIV sector to pay its '*fair share*' of the costs, based on the share of HIV benefits (and treatment cost savings) in total benefits estimated by the cross-sectoral CBA (59). We estimate shares with these three approaches.

Sensitivity analyses

Given that the case study is merely illustrative of various financing approaches, we explore how our results are dependent on changes in intervention cost, monetary valuation of an HIV DALY, WTP thresholds applied and the use of the intervention's weighted effect on the HIV/STI and reproductive health indicators.

Further details on all the parameters used and a technical description of methods can be found in Appendix 1.

Figure 4.1 Cost-effectiveness threshold from the HIV budget holder's perspective



Source: Authors

4.3 Results

As summarised in Table 4.1, we estimate that the intervention averted an estimated 208 DALYs by averting 6 HIV infections, 19 HSV-2 infections, 10 teen pregnancies and 46 depression cases. In terms of education objectives, the intervention led to 193 baseline drop-outs re-enrolling in school, 77 additional years of school attendance and 24 drop-outs averted. Educational attainment was also improved among baseline school girls (conditional arm).

The 18-month intervention targeting 1,225 beneficiaries cost an estimated USD 110,250 (see Table 4.2). Discounted treatment costs saved from the prevented HIV infections are about USD 35,966. We estimate a benefit-cost ratio of 6.4. In the cross-sectoral CBA approach, this intervention would therefore be financed, generating a long-term net benefit of USD 404,088. In all the sensitivity analyses, the intervention would be funded.

Table 4.3 presents the WTP estimates from converting the short-term trial outcomes into total WTP per sub-sector. We find that the HIV sector would be willing to pay USD 31,732 for this intervention, while the other health sub-sectors would contribute USD 66,621 and the education sector USD 62,393.

With the silo approach, where sectors budget in isolation without considering other sectors' benefits, none of the (sub-)sectors would be willing to fund the intervention. The welfare loss (or discounted net benefit forgone) is USD 404,088. However, with the co-financing approach, the sum of each sub-sector's maximum contributions would be greater than the full implementation cost. The intervention would therefore be funded, generating the long-term net benefit and no welfare loss.

The sensitivity analyses in Table 4.3 clearly show that financing outcomes for the silo and co-financing approaches are very sensitive to the total intervention cost and the WTP thresholds per sector. In the higher cost scenario, the intervention would no longer be attractive, even with co-financing. If the health threshold was increased to WHO's upper bound (three times GDP/capita), the non-HIV health sector would fund the intervention. The likelihood that the intervention would be financed will also be greatly influenced by the education sector's WTP. By assuming the lowest ICER in the education literature as the opportunity cost of the investment, such a scheme would not be considered, even with co-financing. Using the weighted intervention effect, the HIV budget holder would be willing to cover up to 68% of the costs.

From an HIV perspective, we find that the HIV sector's share would be at most 29% in the co-financing scenario (range: 12%-86%). However, given the other sectors' contributions, the HIV budget may not need to be tapped at all, as there would be no financing gap left by other sectors.

With the ‘fair share’ approach (Table 4.2), we estimated total long-term benefits and cost savings of USD 514,338, of which 25% were HIV-related (range: 4%-57%). By apportioning intervention costs using this figure, we find that the HIV share would be about USD 27,773. This represents a cost per HIV DALY averted of USD 297 - just below WHO’s threshold.

Table 4.1 Short-term outcomes of the Zomba cash transfer trial

(Sub-) Sector	Outcome	Impacted group (n)	Post-trial difference intervention / control group	Source	Total impact	Total DALYs averted
HIV	HIV infections averted	Baseline schoolgirls (789)	-0.70%	(7)	6	94
Education	Drop-outs re-enrolled	Baseline drop-outs (436)	44.3%	(7)	193	
	Drop-outs averted	Baseline schoolgirls (789)	-3.1%	(39)	24	
	School attendance (additional years)	Baseline schoolgirls conditional arm (506)	10.1% change in full attendance (1.5 yrs)	(41)	77*	n.a.
	English test scores (0.1 SD gains)		0.14 above mean (regression coefficient)	(41)	708	
Sexual & Reproductive Health	HSV-2 infections averted	Baseline schoolgirls (789)	-2.37%	(7)	19	1.1
	Teen pregnancies averted	Baseline schoolgirls unconditional arm (283)	-3.48%	(7)	10	39
Mental Health	Cases of depression averted	Baseline school girls (789)	-5.80%	(40)	46	157

* 51 additional full years of schooling in conditional arm (506*0.902-506*0.801) over 18 months of implementation (1.5 years) = 77 additional years of schooling

Table 4.2 Long-term Cross-sectoral Cost-Benefit Analysis approach

	Base case scenario	Sensitivity analyses			
		Higher intervention costs ($275,625)	GDP/capita valuation of HIV DALY	Higher valuation of HIV DALY	Higher BCR non-HIV
Net intervention costs	**74,284**	**239,659**	**74,284**	**74,284**	**74,284**
Implementation costs	110,250	275,625	110,250	110,250	110,250
HIV treatment savings^	35,966	35,966	35,966	35,966	35,966
Net intervention benefits	**478,373**	**1,055,531**	**416,503**	**852,773**	**2,973,330**
HIV infections and DALYs averted	93,600	93,600	31,730	468,000	93,600
Long-term benefits to education and health (excl. HIV)*	384,773	961,931	384,773	384,773	2,879,730
Benefit-cost ratio (overall)	**6.4**	**4.4**	**5.6**	**11.5**	**40.0**
HIV only	1.3	0.4	0.4	6.3	1.3
Health and education only*	3.5	3.5	3.5	3.5	26.1
Net Benefit	**404,088**	**815,872**	**342,218**	**778,488**	**2,899,046**
HIV benefits and cost savings in total benefits (%)	**25%**	**12%**	**15%**	**57%**	**4%**
HIV sector's 'fair share' (USD)	27,773	32,718	16,495	62,518	4,747
Cost per HIV DALY equivalent (USD)	297	350	176	668	51

* Based on benefit-cost ratio estimated by King et al (2007) for a conditional cash transfer scheme to keep girls in school. i.e. 3.5 – 26 (see Appendix 1 for more detail).

^ Discounted lifetime ART costs per person have been estimated at 2002 USD 9,435 (Cleary et al., 2006) or 2009 USD 11,303: 50% of these costs were considered drug-related and therefore internationally comparable (not adjusted) and the other 50% were adjusted from the ratio of Malawi's GDP/capita to South Africa's GDP/capita.

Table 4.3 Willingness to pay for the Zomba cash transfer intervention per (sub-) sector with the Silo approach and the Co-financing approach

(Sub-) Sector	Outcome metric	WTP per unit (USD)	Total WTP (USD)	% of total programme costs				
				Base case	Higher intervention costs (USD 275,625)	3xGDP/ cap health threshold	Lowest CER for education threshold	Weighted HIV and SRH effects*
HIV	DALYs from HIV infections averted	339†	31,732	**29%**	12%	86%	29%	68%
Education	Drop-outs re-enrolled	220††	42,620	39%	15%	39%	3%	39%
	Drop-outs averted	204††	4,920	4%	2%	4%	4%	4%
	School attendance	163††	12,521	11%	5%	11%	0.3%	11%
	Test scores	3.30††	2,333	2%	1%	2%	1%	2%
Education sub-total			62,393	**57%**	23%	57%	8%	57%
Sexual & reproductive health	DALYs from HSV-2 infections averted	339†	380	0.3%	0.1%	1%	0.3%	0.3%
	DALYs from teen pregnancies averted	339†	13,062	12%	5%	36%	12%	10%
Mental health	DALYs from cases of depression averted	339†	53,179	48%	19%	145%	48%	48%
Other health sub-total			66,621	**60%**	24%	181%	60%	58%
Total potential contributions			160,747	**146%**	41%	324%	97%	183%
Funding outcome	Silo approach		66,621	Not funded	Not funded	Funded	Not funded	Not funded
	Co-financing approach		160,747	Funded	Not funded	Funded	Not funded	Funded

† Malawi's GDP per capita for 2009. Source: World Development Indicators.

††See Appendix 1.

**Weighted percentages estimated by Baird et al (2012) for HIV prevalence, HSV-2 prevalence and pregnancies, to account for variation in the probability of inclusion in the study according to age and stratum.*

4.4 Discussion

This study explored financing outcomes for a structural HIV intervention, based on different decision approaches. We find that allocatively efficient structural interventions may be less likely to be prioritised, financed and taken to scale where sectors evaluate their options in isolation. Existing approaches for assessing the value for money of interventions with multiple outcomes seek to internalise the external benefits, thereby broadening to a societal perspective (35, 36, 60), but are not at present extensively used in resource allocation by HIV decision-makers. A co-financing approach, on the other hand, also minimises welfare loss and could potentially be incorporated in a sector budgeting perspective. Decision rules based on cost-effectiveness thresholds could still support this approach as a potential method to explore the range of contributions from different sector budgets.

Our findings suggest that co-financing would be worth considering for programmes that are relatively low-cost, but for which no sector is willing or able to finance the full costs. It may also only work if WTP thresholds from each sector's perspective are clearly defined and are solely based on their own objectives. For example, if measures of HIV outcomes are used that include wider social benefits (not just welfare gains from disability) there may be the risk of double-counting benefits. Whilst WTP for DALYs is relatively well-defined, we were not able to identify similar international WTP thresholds for the education sector – and thus may overestimate the education sector's WTP. That being said, several potential poverty reduction and gender equity benefits from such an intervention were not measured by the trial and could have offset this effect.

It should also be noted that the use of normative cost-effectiveness thresholds as decision rules in health has been questioned (29, 46) and even WHO's lower threshold is perceived as being too high to serve as a useful decision rule in many low and middle-income settings. Nationally-determined thresholds could overcome this.

Another concern is that these thresholds may not reflect sectors' budget constraints. However, in this case, affordability may not be a major issue. Based on a previous analysis, the annual cost of this cash transfer scheme targeting all poor girls in Malawi currently in secondary school (44) would be about USD 3.2 million. The education sector's maximum share of 57% or USD 1.8 million, would represent 0.8% of the national education budget in 2011/12, while the health sector's share (USD 1.9 million) would be 0.9% of the health budget (61). Although not necessarily required, the HIV sector's maximum share of 29% or USD 928,000 would claim 1.2% of the national HIV budget (61). Clearly, what is important is the relative effectiveness of investing these amounts in the next best HIV, health or education programme, but the investment as such does not appear unsustainable.

Using a co-financing approach has implications for the design of HIV interventions, because certain elements could be particularly critical to specific sector objectives and thus important

for the financial viability of the intervention – even when not directly beneficial for HIV itself. For example, removing the conditionality of the cash transfer may reduce the cost of the intervention (62), without impacting HIV outcomes, but may affect educational outcomes, making it less attractive for the education sector and therefore less likely to be co-financed.

Co-financing may provide an opportunity to realise development synergies, but it will require effective cross-sectoral coordination mechanisms for planning, implementation and financing. These may entail transaction costs that could influence the cost-benefit equation. There are several possible ways to achieve this. The first-best (and more efficient) approach would be for budget allocations to structural interventions to be incorporated at a centralised Ministry of Finance/Treasury level, before budgets are allocated to sectors. This may be possible as part of joint public expenditure planning processes (e.g. Medium-Term Expenditure Frameworks), but in practice may fall through the gaps given their complexity. A second-best scenario could involve setting up a basket funding mechanism, whereby other sectors become donors of a programme that would be implemented by a single line ministry. Some examples of such joint budgeting initiatives for health and social care can be found in high-income countries (63-65), generally targeting specific patient groups or broader health promotion efforts. In countries where donor funds are important, this could also be a mechanism by which multilateral or bilateral aid earmarked for HIV is channelled towards structural approaches. National AIDS Coordinating Authorities operating as supra-ministerial and cross-sectoral coordination bodies in several countries, could play a key role in facilitating such processes and serving as an example for other cross-sectoral issues (66).

In our analysis, we modelled the share from the HIV budget, assuming that different sectors adopt a co-operative stance. If sectors are more combative, negotiation could lead to them understating their WTP to let others cover the costs, leading to unfunded or underfunded interventions – akin to a coordination game like “chicken” in game theory. This may be exacerbated where other sectors consider that the HIV response has received a disproportionate amount of external financing (23). Other governance challenges are to be expected related to the feasibility of sector line ministries and sector-orientated donors agreeing to pool budgets, since this would imply a loss of control for some.

Whichever institutional approach is adopted, the co-financing approach is likely to be data-hungry, since evidence of impact across sectors is required. Findings will also depend on which benefits are evaluated and modelled, as the fewer benefits considered, the higher the HIV share. As a starting point, interdisciplinary evaluation approaches, building on an evidence-based theory of change could be a way to ensure that the most plausible benefits are captured. Another concern is that ICERs fail to capture disparities in health gains between different groups and using them as decision rules therefore excludes equity objectives from the equation. This could potentially be mitigated by considering extended ICERs (67).

Finally, it should be noted that economic evaluation is only one input (at best) in the inherently political process of priority-setting. Several other factors influence financing decisions, such as affordability, historical budgets, equity, etc (23). These may be increased when decision-making covers multiple sectors. Although efforts have been made to improve decision modelling to factor in a wider range of criteria (68-70), to date, the process by which value for money data and other factors are translated into resource allocation remains a black box. In a recent prioritisation exercise based on CBA studies of 17 HIV interventions in sub-Saharan Africa, the same cash transfer intervention was ranked third by African Civil Society, fifth by American students and tenth by a panel of economic Nobel laureates (71). This illustrates how the same economic data can lead to quite heterogeneous financing decisions, underlining the need for a transparent deliberative process, whereby value judgements are made explicit and resource allocation is a weighted reflection of societal preferences (72).

4.5 Conclusion

In the new constrained economic climate, sustainable financing for HIV responses is urgently needed. Alongside the conventional sources of public financing(73), co-financing of structural interventions could potentially be an additional avenue that has not been sufficiently explored. Otherwise, structural interventions may be under-funded and their cross-sectoral benefits foregone. Co-financing provides an opportunity to avoid the current zero-sum nature of silo approaches to budgeting, whereby HIV's gain is another sector's loss. Instead, some structural approaches have the potential to result in a 'win-win' situation in which multiple HIV, health and development objectives are achieved simultaneously. Embedding HIV responses into broader national priorities would further encourage domestic ownership and sustainability.

Therefore, we suggest that HIV programmes actively seek opportunities to co-finance development efforts that have been shown to produce direct HIV benefits, with the magnitude of the benefits informing the resources invested. This would help realise the promise of development synergies, accelerate progress across the Millennium Development Goals and shape new models of governance and financing in the post-2015 era.

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Principal Supervisor	Prof Anna Vassall
Thesis Title	Cross-sectoral co-financing: Taking a multi-payer perspective in the financing and economic evaluation of structural HIV interventions

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Student Signature:  **Date:** 23/10/2017

Supervisor Signature:  **Date:** 29/10/2017

CHAPTER 5 Cost-Effectiveness Thresholds in Global Health: Taking a Multi-sectoral Perspective

5.1 Introduction

Health policymakers across the globe are facing difficult financing decisions having to balance a large unmet and rising demand for health services, costly new drugs and technologies, ambitious international guidelines; and severely constrained health budgets (1). To aid these decisions, a threshold is sometimes used to determine which interventions are cost-effective and should therefore be included in a prioritised package of health interventions (2). For over a decade, the Commission for Macroeconomics and Health and the World Health Organisation's suggested threshold of one to three times a country's GDP per capita per disability-adjusted life year (DALY) averted was accepted without much debate, or theoretical basis (3, 4). However, there is now a general consensus that these thresholds may not reflect the real opportunity costs of investing in an intervention and that their application may cost lives (5-8).

There have been recent efforts to provide clarification on what the threshold should represent, rooted in different economic traditions (6, 9, 10). In a welfarist framework that accepts that the individual knows what is best and where aggregate individual utility is the maximand of public policy, a threshold could be derived from the marginal utility gained from the consumption of goods or services that produce health (7, 11). This demand-side concept may be utilised, alongside other criteria, to set the 'health' budget, in relation to other uses of public resources. Decisions of how to then spend a constrained health budget can be better guided by an extra-welfarist framework, in which 'health' in itself is intrinsically valued and health maximisation is the decision maker's objective (12, 13). The decision rule to allocate resources to a specific intervention is then based on a supply-side threshold that reflects the marginal productivity of the health system (9, 14, 15).

This conventional approach that underpins many health economic evaluations often focuses on a single sectoral payer that seeks to maximise health, typically through interventions delivered by the health care system. This approach risks missing two critical issues: firstly, multiple 'sectors' contribute to the production of health, and secondly, some of the goods and services produced by the 'health sector' – or the health care system, have multiple benefits besides health (16, 17). There is a solid and growing body of evidence on the social determinants of health, which include poverty, education, gender inequity, housing and transport, among many others (18-21). In fact, some argue that population health is largely or even primarily impacted by interventions in other sectors with other payers, who are arguably not aiming to maximise health (22, 23). In the new global development agenda, these structural

determinants have come to the forefront, with 17 sustainable development goals that explicitly seek to tackle socio-economic inequalities and environmental factors hampering human development (24, 25). Global health programmes will increasingly have to compete for resources with these upstream non-health programmes, but could also stand to greatly benefit from their spill over health outcomes. Similarly, public health interventions targeting populations or communities, rather than individuals, typically have wide-ranging cross-sectoral impacts and cost implications. The spill over benefits of these interventions have gained prominence and helped to make the case for greater investments (17, 26, 27).

There are currently a number of ways to deal with the economic evaluation of interventions with multi-sectoral outcomes (17, 28-30). The first is the adoption of a welfarist cost-benefit approach that monetises outcomes. Analysts grappling with this in the fields of social care and environmental economics are leaning towards this option (29, 31). Yet the contentious step of attaching a monetary value to life, health and other social outcomes is part of what led to the development of and health decision-makers' preference for an extra-welfarist framework (14). Within the extra-welfarist evaluation perspective, two approaches exist that allow those in the health sector to incorporate non-health consequences in their decision space. Most commonly, costs are weighed against (a) composite outcome measures that incorporate broader capabilities; or (b) multiple consecutive outcome measures, with cost-consequence approaches (28, 32).

Several current guidance documents also stipulate a variation of the latter approach, whereby the non-health costs and effects of interventions are to be reported and disaggregated by sector of the economy or payer – including the Gates Reference Case for economic evaluation in global health, the National Institute for Health and Care Excellence's (NICE) guidance for local government decisions in England and Wales, and the second US panel's recommendations on cost-effectiveness analysis in health and medicine (33-36). The latter has even recommended the standard reporting of two reference cases for every economic evaluation: one from a health care sector perspective and one from a broader societal perspective, with the use of an impact inventory to comprehensively report consequences beyond the formal health care sector (36). Following the same logic, evaluations of non-health interventions should similarly consider non-negligible health consequences. However, even with impact inventories for interventions across sectors, current guidance remains silent on how a health payer should value consequences outside the sector, in order to decide on the most judicious allocation of its resources.

Although the second US panel "recommends that analysts should attempt to quantify and value non-health consequences", it also acknowledges that "there are no widely agreed upon methods" for this and it remains unclear how to apply an 'opportunity cost' based threshold to non-health impacts in order to support investment decisions (36). In the UK, NICE guidance further points out the lack of a standard method to apportion costs when more than one

government department or local government is involved in delivering an intervention or is reaping its benefits (34, 37).

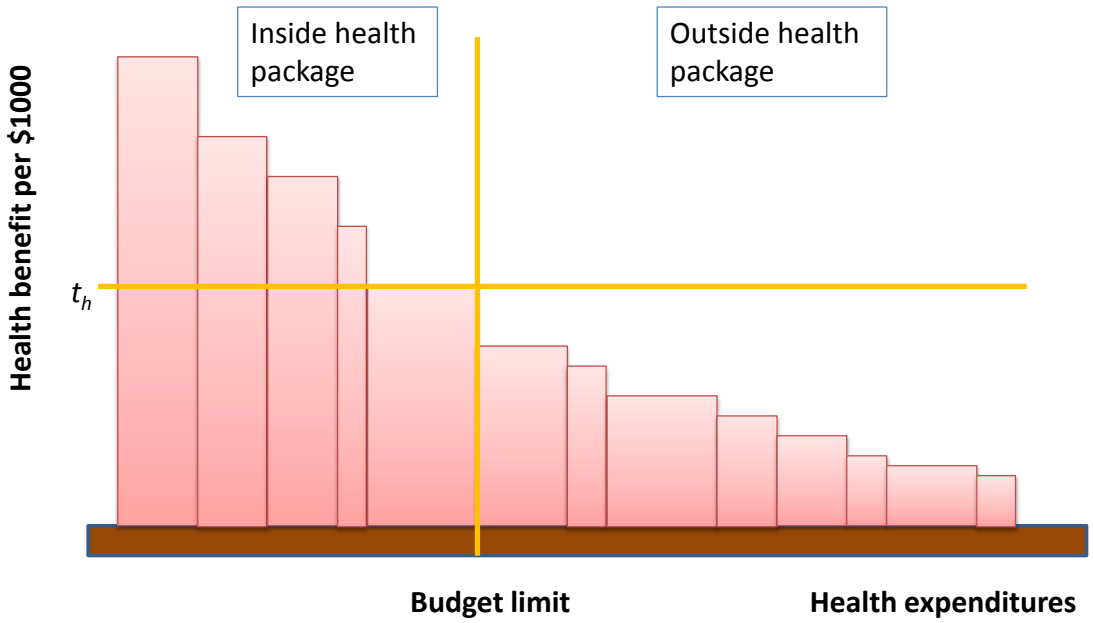
In this paper, we examine how efficient current cost-effectiveness thresholds are in dealing with interventions with multi-sectoral outcomes, implemented within and outside the health sector, and how this could be improved. We propose an approach that retains the extra-welfarist perspective (that may also apply to payers in other social sectors) and the principle of opportunity cost to maximise each sector's objectives, recognising that each sector has its own budget constraint and real opportunity cost. We start by illustrating how the current thresholds could result in health losses, before proposing a potentially more optimal second best approach. We then discuss some of the associated measurement and application challenges, and highlight areas for future research.

5.2 Approaches to resource allocation: What are the consequences of a unisectoral approach?

Culyer (2015) has recently proposed a bookshelf metaphor to resource allocation in health, whereby each book represents a health care intervention (see Figure 5.1) (38). The height of the book indicates its effectiveness in terms of health benefit, and its thickness captures its total cost. These books can be ranked in order of their height, from left to right, and included in a national health care package up to the point where the health budget is exhausted – similarly to the league table approach (3, 5). The last intervention to be included therefore represents a threshold, t_h, of health productivity per unit of expenditure, or the inverse of the common cost-effectiveness ratio. It is the least productive intervention provided and any intervention that would be considered to be added to the package, would have to be at least as productive in order to avoid a loss of population health. The threshold is a direct function of the productivity of health interventions and the size of the health budget.

If such a unisectoral approach is to achieve health maximisation, one must make a number of assumptions, including: (i) that the health budget reflects the allocation of public resources to health care rather than to 'health'; (ii) that the cost of any health-producing intervention under consideration is fully borne by the health budget; and (iii) that the merit of any intervention is solely determined by its impact on population health. However, a health-producing intervention delivered outside the health sector (or a public health intervention) is likely to have other non-health benefits, and thus other payers that are willing to allocate part of their budgets to it. We suggest and illustrate how, in such cases, these underlying assumptions may result in health losses. From here on, we refer to 'non-health interventions', as interventions with non-health primary objectives and spill over health outcomes; while 'public health interventions' will have public health as a primary objective and spill over non-health outcomes.

Figure 5.1 The bookshelf of health care resource allocation



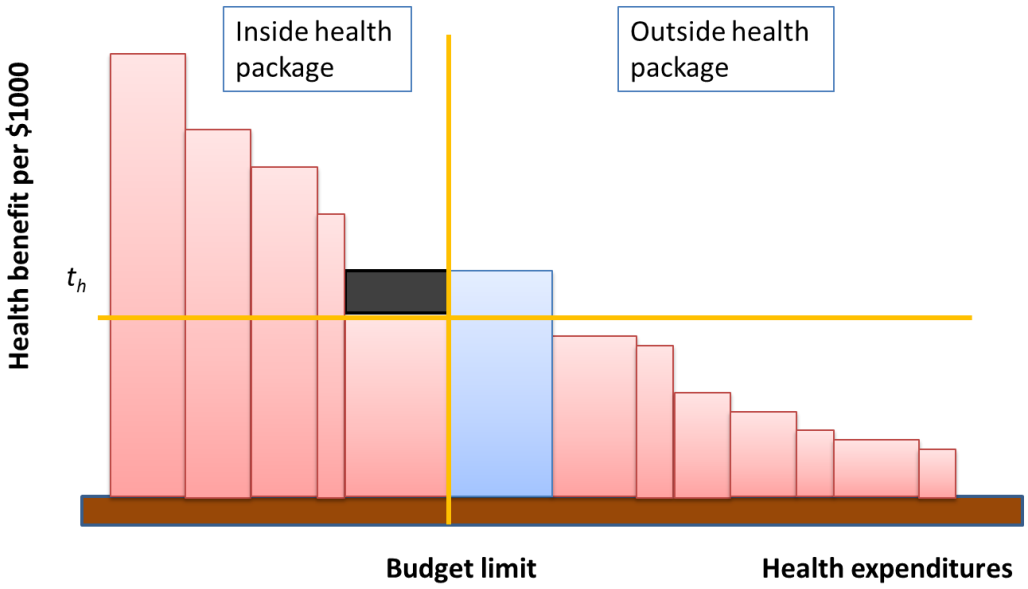
Source: Adapted from Culyer (2015)

First, we examine what the 'bookshelf' would look like if the 'health' budget is provided to a payer maximising health, but that can only fund health care services to do so. We consider a stylised case where the exogenous government budget is split between two sectors or payers: a health payer and an education payer. We also assume that the education payer does not have health maximisation as an objective, and would need to fully fund any intervention if it were interested in its education benefits. It would follow a similar prioritisation approach as the health payer, with its own books ranked on a bookshelf according to education productivity. In this case, any intervention that improved health but was not provided within the health care system, even if more efficient, would not be prioritised, unless its education benefits were sufficient to justify the education payer fully funding it (for example the blue bar in Figure 5.2). If not, this would be at the cost of lives and/or quality of life – as represented by the black area in Figure 5.2. In reality, there may be specific activities or tweaks of interventions in other sectors that would optimise their positive health externalities, or mitigate their negative health externalities, that would be better value for money than certain existing health care interventions (16). For example, adding health modules in schools' life skills curricula, or providing micronutrient supplementation in schools could be relatively low-cost interventions with significant education, health and economic benefits, but they have not always been embraced by the health sector (39).

Second, we examine a situation where the 'health' budget is provided to a payer maximising health, who can fund any health or education intervention to do so. We assume that the education payer still does not have a health objective, interventions are indivisible (40), and

one payer must bear the full cost of an intervention. In this case, some interventions may not be funded, because they do not generate sufficient return in either sector, such as book 6 in Figure 5.3 a/b.

Figure 5.2 Health loss from exclusion of non-health care interventions

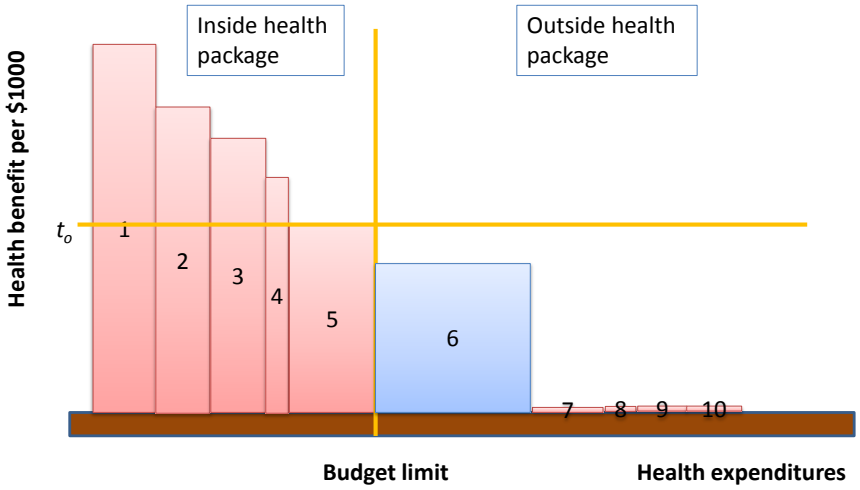


Note: *Pink books are health care interventions, while blue books are non-health care interventions. The black area represents the health loss from the exclusion of the latter in the prioritisation process.*

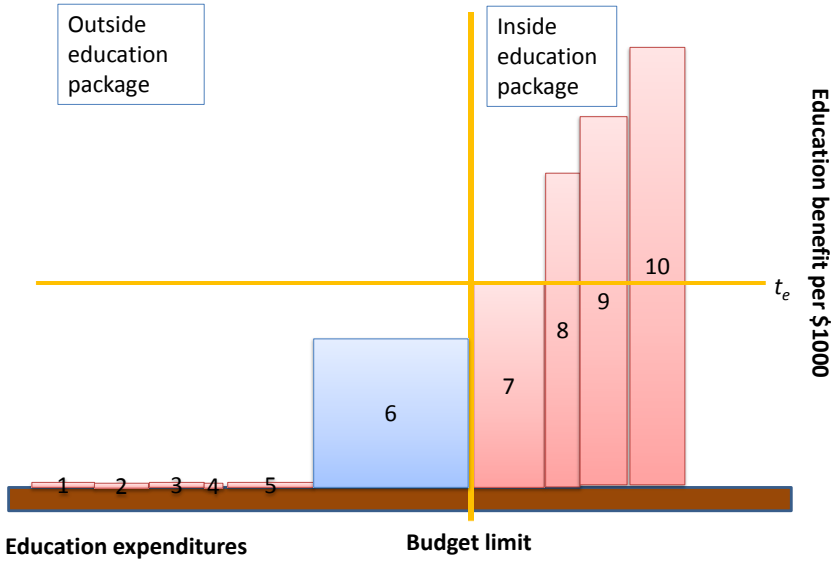
Take the example of an education reform in Botswana. In 1996, the government reformed the grade structure of secondary schooling, effectively extending it by a year. Through a natural experiment, De Neve and colleagues found that this led to 0.79 additional years of secondary schooling among the affected cohorts, with each added year reducing HIV risk remarkably by 8 percentage points (41). From the health payer's perspective, at a cost per HIV infection averted of USD 27,753, this would have been a less good investment than other HIV interventions, like male circumcision or treatment as prevention (ranging from USD 550 to USD 8,375) (41), and it would not have been prioritised. Although in this case it was actually implemented by the education sector, one could imagine a scenario where there could have been more efficient education policy options to achieve the same educational impact, and even the education payer may have chosen an alternative investment without health spill overs.

Figure 5.3 Potential undervaluation of interventions with multi-sectoral benefits

a) Health payer perspective



b) Education payer perspective



Note: *The books numbered 1 to 5 are health care interventions, while the books numbered 6 to 10 are education interventions. The horizontal axis in figure a) should be read from left to right, while the horizontal axis in figure b) should be read from right to left.*

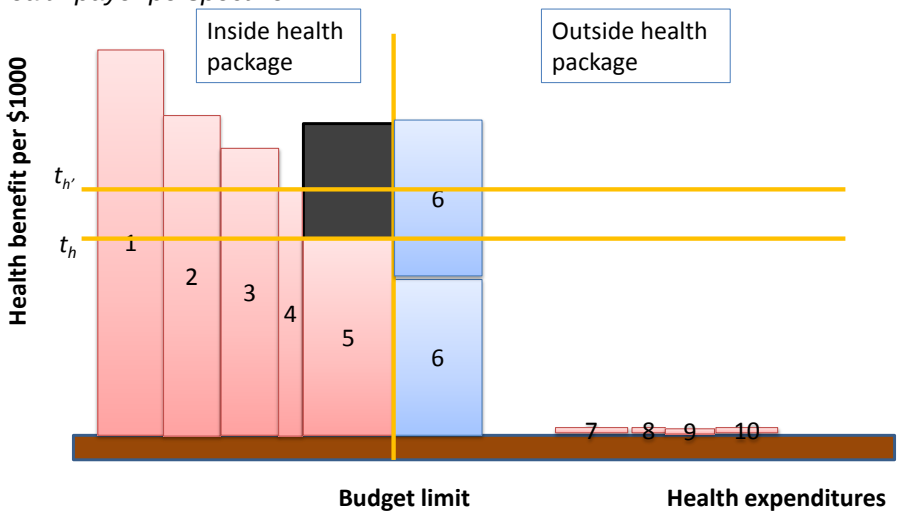
However, if we drop the assumption of indivisible costs and allow multiple payers for one intervention, then the health care cost (or contribution) could be lower than the total intervention cost. The health productivity of an education intervention per health dollar spent would therefore increase, as would its education productivity. For example, if the cost of intervention 6 would be shared equally, then its health and education productivity (per unit of expenditure) would

double, making it better value for money than health intervention 5 in Figure 5.4a, and education intervention 7 in Figure 5.4b. This would allow both payers to prevent losses of health and education outcomes – depicted by the black areas in both figures. As a consequence, both sectors' thresholds would shift up in terms of health/education gain per dollar spent, from t_h to $t_{h'}$ and from t_e to $t_{e'}$ (in Figures 5.4a/b) reflecting the previous inefficiencies in each sector.

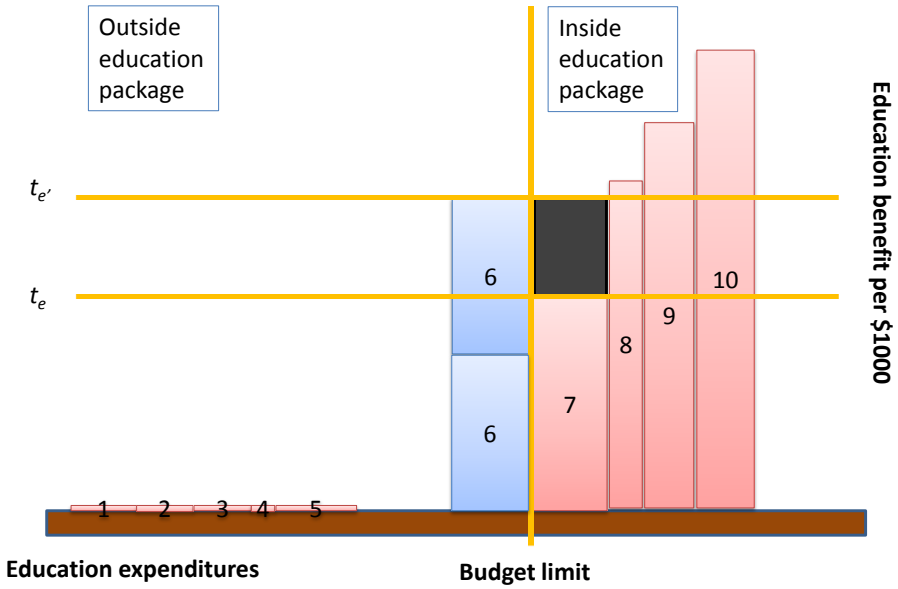
A real-life example of this is a USD 110,000 cash transfer intervention in Malawi targeting girls of school-going age to keep them in school, which was found to have a range of health, education and gender outcomes (including averting 94 HIV DALYs) (42). However, the initial analysis that only took the perspective of HIV impact, indicated that it would not have been cost-effective and the HIV budget holder would not have paid the full cost. However, after incorporating the other outcomes and payers' cost-effectiveness thresholds, the HIV sector was found to only need to allocate up to USD 29,000 to the intervention, bringing its HIV productivity up from about USD 1,170 per HIV DALY averted to USD 339 (43). Such a 'book' would become taller in this scenario and excluding it from the health budget could result in a loss of health (as represented by the black area in Figure 5.4a).

Figure 5.4 Health and education losses from measuring productivity as a function of total costs instead of health or education costs

a) Health payer perspective



b) Education payer perspective



Note: Pink books are interventions with single sector benefits, while the blue book is an intervention with multi-sectoral benefits. The area in black represents the health/education losses of not allowing for cost-sharing. The horizontal axis in figure a) should be read from left to right, while the horizontal axis in figure b) should be read from right to left.

5.3 Potential Solutions to enabling multi-sectoral synergies

In a 'first best' situation, we would imagine a central purchaser of social welfare (including health and education gains) with perfect information. This payer could choose all the most efficient interventions to maximise social welfare, regardless of which sector they were implemented in. the efficiency gains illustrated in Figure 5.4a and 5.4b above would be realised by allocating 'health resources' across sectoral budget holders (ministries) bearing their interventions' spill

over benefits and costs into account. This would result in the budgets allocated to each sector shifting accordingly: the health sector budget would shrink (pushing out intervention 5 in Figure 5.3a), and the education budget would grow to include intervention 6 (after excluding intervention 7 in Figure 5.3b).

However, in reality, there is often no perfectly coordinated and informed central decision-maker. Overall sectoral budgets are set, and then public investments in one sector tend to be evaluated independently from investments in other sectors, which are taken as 'given'. This is known as the 'second-best' constraint of real world public sector decision-making (44, 45). In practice, governments are therefore more likely to allocate their health outcome-earmarked budget in full to the Ministry of Health (MoH) with the mandate to maximise population health. Institutional mandates and policies thereafter tend to constrain ministries of health to allocations to health care alone (13, 44, 46).

Accepting the 'second best' scenario, a pragmatic option to achieve a more optimal allocation is that the health payer (MoH) could redistribute part of its budget to other sectors, where specific non-health interventions achieved a health gain more efficiently than the health sector's marginal productivity (opportunity cost) – hereafter referred to as a 'co-financing' approach. Likewise, non-health sectors could transfer part of their budgets into a 'co-financing' mechanism where public health programmes generate benefits that they are also interested in. This 'co-financing' approach recognises the opportunity costs of different payers, but at the same time enables additional improvements in both health and other sectors, and a means to finance often highly efficient upstream non-health or public health interventions (43).

Although we focus on benefits here, a similar approach could be taken for interventions that impose costs on other sectors or reduce their benefits through negative externalities. For example, if a specific health intervention led to an increase in the costs of an education intervention, the education sector could end up foregoing education benefits from having to keep a now 'thicker' book on its shelf, and drop a more productive one. We could think of the inclusion of a health education subject in the curriculum, whereby schools may hypothetically have to divert teachers and available school hours away from other important subjects, negatively affecting students' learning in those areas. If these negative spill overs were taken into account, the education sector could potentially be compensated through a larger share of the budget, if the resulting health losses from a reduced budget were valued less than the education losses.

While not widespread, in practice, this co-financing approach is not unheard of. In some high-income countries, like the UK and Sweden, there have been initiatives to pool budgets between health and social care for the management of chronic health problems and disabilities in particular, in order to overcome narrow sectoral interests and achieve efficiency savings (26, 47). In certain global health programmes, investment plans have been developed that include multiple sectors and health-producing interventions outside the health sector, as well as large

scale public health interventions with wide-ranging effects. For example, the global strategic investment framework for HIV identified structural interventions as integral components of effective responses, including community mobilisation, social protection and education programmes, alongside basic HIV programme activities like condom programming and antiretroviral therapy (48). Specifically, the South African HIV/Tuberculosis Investment case has included partial funding for child-focused cash transfers, and school feeding, among others, even though these would be implemented in other non-HIV sectors (49).

5.4 Challenges and Areas for Future Research

At its core, any 'co-financing' approach requires a clear identification of a range of intervention outcomes and the sectoral payers benefiting from the intervention. The second US panel's recommendation of a multi-sectoral impact inventory can be highly useful in this respect. It would provide analysts from other sectors the required information to support decisions on what they may be willing to pay for 'their' share of benefits generated by a health intervention, and it would encourage those within the health sector to explore 'co-financing' arrangements to enable such transfers. The same would be true for non-health interventions. In low and middle-income settings, where resources may not be sufficient to cover large-scale social programmes like universal primary education, for example, analytical and institutional approaches that do not highlight and value multiple benefits, may have particularly high opportunity costs.

Co-financing also require changes in public finance mechanisms to ensure that interventions can be funded from different sectors. While Claxton and colleagues demonstrated that public health interventions with multi-sectoral costs and benefits should be funded if other sectors could compensate the implementing sector *in principle* (13), in practice this compensation would need to be real and a mechanism would need to be in place to allow for it. Moreover, it is worth noting that while we simplified each sector to a single payer, there are likely to be more payers with similar objectives, but separate budget constraints. In low and middle-income countries, for example, where there is significant external development assistance for health, there would be separate health payers, namely a national public payer and donors, each with their own thresholds. Even within government, it may be relevant to consider the various levels of resource allocation, especially where local governments are increasingly managing decentralised and often unearmarked budgets (34, 50).

Capturing and measuring multiple programme outcomes is a significant challenge given data scarcity, with many evaluations of global health interventions focusing on within sector primary outcomes, rather than exploring a range of sectoral outcomes. It would also come at a cost, and would only be warranted in as far as the additional non-health consequences are significant enough to effect the results of the analysis, as has been recommended in the second US panel (36). In addition, the 'co-financing' approach requires the determination of thresholds for

different sectors in order to estimate each payer's potential contribution (43). The application of thresholds varies by sector, with some having cost-effectiveness thresholds and other sectors adopting cost-benefit approaches (29). Two empirical approaches are currently being explored in health and could be applied to other sectors. The first searches for this threshold through econometric analyses of health care expenditures and health outcomes to estimate marginal productivity (9). Another approach is to search for the threshold by identifying the least cost-effective intervention included in the package and the most cost-effective intervention excluded, based on published literature (38). While both approaches are promising, they require substantial data, and may be difficult to apply in some sectors with less developed economic evaluation frameworks, and where a critical mass of economic evaluations is not available (29, 51, 52).

Given the importance of financing multi-sectoral interventions, analysts may also consider using more pragmatic approaches to estimate these thresholds, possibly exploring willingness-to-pay elicitation from decision-makers, and expert-informed threshold searching. Eliciting decision-makers' WTP for a gain in a unit of outcome from the production of a service, requires the assumption that this is their best estimate of the opportunity cost. However, such a measure is likely to incorporate more than the criterion of efficiency, and may be higher than the marginal productivity of the existing service package, as decision-makers will have imperfect information, and would rightly have other criteria that determine their willingness-to-pay in practice, such as equity (53, 54). Their estimate of willingness-to-pay is at best likely to conflate these aims, and thus overestimate the threshold, or be more aspirational (7). Another potentially more promising approach would be to use decision-makers as experts to identify the perceived least efficient intervention they are currently implementing, and the most efficient they are not implementing, as a starting point, and then review evidence on their cost-effectiveness. However, both of these methods need further exploration and validation against the range of empirical approaches currently being developed.

5.5 Conclusions

Good health is a function of a range of biological, environmental, behavioural and social factors. The consumption of quality health care services is only part of how good health is produced. Although few would argue with this, the economic framework used to allocate resources to optimise population health is applied in a way that constrains the analyst and the decision-maker to health care services. As a result, lives and quality of life may be lost. We propose a second best approach to decision rules for health-producing interventions in non-health sectors, and public health interventions with multi-sectoral effects, that could bring a health decision-maker closer to maximising population health in general, rather than through health care alone. This would require the health payer to co-finance such interventions with other sectors, based on its cost-effectiveness threshold. Likewise, other sectors would determine

how much to contribute towards such an intervention, given the current marginal productivity of their budgets.

The co-financing approach is embedded in the prevailing extra-welfarist framework of health economic evaluation. It does not fundamentally question the framework, but provides a theoretically consistent mechanism to bridge the health evaluative space with other evaluative spaces, thereby going beyond a single health outcome to bring allocations closer to the general equilibrium that is sought in a welfarist framework. It fully aligns with the decision-maker's perspective, whereby the focus is on societal objectives (such as population health), rather than aggregate individual utility (12, 14, 15, 53).

However, the data and analytical demands of estimating cost-effectiveness thresholds across multiple payers may hamper the realisation of such an efficiency-enhancing co-financing mechanism. Further research is called for to test and validate various measurement approaches, in order to support the optimal allocation of resources to global multi-sectoral and public health interventions going forward.

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SECTION A – Student Details

Student	Michelle Jeanette Sayi Remme
Principal Supervisor	Prof Anna Vassall
Thesis Title	Cross-sectoral co-financing: Taking a multi-payer perspective in the financing and economic evaluation of structural HIV interventions

If the Research Paper has previously been published please complete Section B, if not please move to Section C

SECTION B – Paper already published

Where was the work published?	Social Science and Medicine		
When was the work published?	September 2016		
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion	N/A		
Have you retained the copyright for the work?*	Yes	Was the work subject to academic peer review?	Yes

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Where is the work intended to be published?	
Please list the paper's authors in the intended authorship order:	
Stage of publication	Choose an item.

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	I was the lead author of this paper and conceptualised it with AV. I designed the analysis and conducted it together with MS. OS supported with the neighbourhood econometric models. I drafted the full manuscript and made revisions based on comments from AV, CW, OS, MN and MS.

Student Signature:  **Date:** 23/10/2017

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CHAPTER 6 Financing the HIV Response in Sub-Saharan Africa from Domestic Sources: Moving Beyond a Normative Approach

6.1 Introduction

Despite optimism about the end of AIDS, and remarkable progress towards this ambition, a sustained HIV response will be required for years to come. HIV remains the fifth global cause of morbidity and mortality, and ranks second in sub-Saharan Africa (1). Unprecedented resources have been mobilised in response to the epidemic, reaching USD 19.1 billion in 2013 in low and middle-income countries. Yet, this still falls short of UNAIDS' previous resource needs estimates of USD 22-24 billion by 2015 and its USD 36 billion estimate for 2020 in the ambitious 'fast-track' scenario that would seek to reduce the number of new infections and AIDS-related deaths by 90% by 2030 (2).

With the success of antiretroviral therapy (ART), HIV infection is no longer a death sentence, and national governments face the challenge of how to sustain their growing obligations and duty to maintain people on life-long treatment (3), alongside laudable commitments to continue scaling up treatment access for all those who are HIV-infected (2), and the need to continue investing in HIV prevention to reduce the rate of new infections. This challenge is substantial. A recent paper estimates the fiscal consequences of this moral duty to treat (4). The figures are stark. In a scenario where 81% of people living with HIV with CD4 counts below 350 mm^3 are on ART, the fiscal obligations of treatment alone until 2050 have been conservatively estimated at 21% of current Gross Domestic Product (GDP) for South Africa, and 80% of current GDP for Malawi, among others (4). The International Monetary Fund (IMF) sets the 'sound' threshold for the debt burden of countries at 40% of GDP, and therefore this hidden HIV-obligation is potentially of real economic concern for both governments and donors. Some now argue that HIV is a fiscal as well as a public health crisis, particularly in sub-Saharan Africa (4, 5).

To date, much of the HIV response across the region has depended on international financing: only 10% to 22% of HIV expenditures in 2013 were financed from domestic sources in low-income and lower-middle-income countries respectively (2). However, with the flat-lining of external HIV funding commitments, optimistic economic growth forecasts and the prospects of increased revenues from natural resources (5), several global and regional declarations have called for African governments to fund more of their own responses (6-8). This, it is argued, would allow donors to refocus their resources on countries that most need external support (7). In addition, there is a growing promotion of 'innovative financing' mechanisms – such as

earmarked taxes or diaspora bonds (9, 10) – to create new sources of HIV financing. A withdrawal or re-allocation of donor financing, without a compensating domestic financing response, may affect the continuity of care for those on treatment, and/or have high opportunity costs by removing financing from other critical areas of domestic spending both within or beyond the health sector. Paradoxically, some of these other areas of spending may also be fundamental to the effectiveness of the HIV response, such as education or the strengthening of health systems (11, 12). It is therefore important to understand the factors that influence countries' potential ability to sustainably fund their national HIV response, without negatively impacting on spending in other critical areas or undermining macroeconomic conditions.

Previous investigations into the amount of domestic financing available for the HIV response have not been comprehensive or formally adjusted for past patterns of financing. These analyses may have been overly simplistic; providing a partial understanding of the overall potential financing available. Some have analysed the determinants of domestic financing for HIV or the potential of specific financing sources (6, 7, 9, 13-16). However, none of these studies considered options under all of the potential sources for generating new resources (revenue mobilisation); sharing existing resources differently (reallocation); and spending existing resources better (efficiency gains). Previous analyses have only considered spending for services within the health or HIV boundaries, and do not consider how spending in other sectors that also influence health or HIV may contribute to effective financing of the HIV response. Finally, most estimates of domestic financing for HIV to date have used normative targets in areas such as allocations to the health sector and general revenue generation capacity, assuming that these norms can be reached (7), although there is one previous study that examines whether countries can achieve levels of spending observed among their peers (6), but does not examine whether these levels are optimal.

Focusing on the 14 most HIV-affected countries in SSA, this paper explores the potential to expand domestic financing for HIV from a comprehensive range of domestic sources, including general health and cross-sectoral financing streams. We examine the financing system as a whole, incorporating changes in efficiency of spending, as well as revenue-raising. We use two approaches: one focused on achieving a range of financing targets - our 'normative' approach; and the other that incorporates previous fiscal behaviours, to try to incorporate the 'real world' constraints on domestic financing. For the latter, we examine historical fiscal data to explore how much changes in key characteristics of domestic public finance (such as proportional spend on health care) have led to changes in HIV expenditure. In doing so, we aim to demonstrate a comprehensive empirical approach to estimating the available domestic financing for HIV, and provoke discussion on the appropriate policy response and allocation of international financing for the HIV response in the coming years.

6.2 Methods

We applied the concept of 'fiscal space' to explore how much additional public financing could be made available for HIV in the next 5 years, in the 14 sub-Saharan African countries with the largest HIV epidemics and expected fiscal burdens (3, 17)– South Africa, Nigeria, Kenya, Mozambique, Uganda, Tanzania, Zimbabwe, Malawi, Zambia, Ethiopia, Lesotho, Botswana, Namibia and Swaziland. These include the 10 countries with the most people living with HIV (PLHIV) and all hyperendemic countries, with adult prevalence above 15%. Together they account for 85% of the disease burden in the region, in terms of number of PLHIV (17). Our analysis focused on the medium-term, i.e. the next 5 years, given the uncertainty around the macroeconomic and political context in the longer run, but we discuss the implications for addressing the substantial economic challenge of HIV financing in the coming decades.

In public finance, 'fiscal space' is used to describe the budgetary space available to allocate public resources to a specific objective, without damaging other developmental or macroeconomic objectives (18, 19), including fiscal sustainability. The potential sources of fiscal space for HIV are similar to those for health services generally, but may vary across countries. Theoretically, domestic sources include: (1) conducive macroeconomic conditions through economic growth, (2) improved taxation/revenue generation, (3) borrowing, (4) reprioritisation (within the government or health budget), (5) sector-specific earmarked sources of revenue, and (6) efficiency gains (20-22). An additional external source is external grants.

To explore which financing policy options have the most potential to create fiscal space for HIV – measured as increased public HIV spending – we followed two approaches. The first 'extended normative' approach considers what countries *could be spending*, given their fiscal position, health system and epidemic context. We estimated how much fiscal space could be created for HIV in a specific country by reaching a normative target or benchmark, using a comprehensive set of fiscal space sources, and holding all other factors constant. For example, how much more could a country spend on HIV if the health share in government spending was increased to the so-called Abuja target of 15% that was agreed upon in 2001, and HIV spending increased proportionately? These estimates are likely to be optimistic and can be seen as representing an upper bound estimate of fiscal space.

In the second approach, we seek to challenge these optimistic estimates to reflect some of the uncertainty around the impact of each fiscal policy change on the fiscal space for HIV, by incorporating empirical evidence on how the different fiscal levers were associated with public HIV expenditure in the past. This empirical approach aims to explore which financing options are most likely to translate into real increases in public HIV resources based on past behaviours. To do this, we developed econometric models to test to what extent variation in public HIV spending between countries may be explained by variation in the different fiscal levers. This second approach incorporates the possibility that changes in fiscal indicators may not always 'trickle-down' to changes in public HIV spending. For example, an increase in the

share of health in the national budget may result in a decrease in the relative share of HIV in the heath budget, if policy makers are satisfied with levels of HIV spending.

Data sources

We used publicly available data on the latest fiscal, macroeconomic, epidemiological, expenditure and health system data available between 2008 and 2012. A full description of all data sources is contained in Appendix 2. We analysed the fiscal space implications for the 14 selected sub-Saharan African countries, but for the empirical approach, we used a cross-sectional dataset of 92 countries. Table 6.1 presents its summary statistics. We did not impute missing values, potentially underestimating fiscal space in certain countries, when country-specific data was not available. All monetary figures are expressed in 2014 USD.

Table 6.1 Summary statistics of the variables in the regression analyses

Variable	n	Mean	Standard deviation	Min	Max
Public HIV Spending per PLHIV (USD)	92	347	565	2	3,191
GDP per capita (USD)	92	3,225	3,173	239	11,695
Adult HIV prevalence (%)	92	3%	5%	0%	27%
Control of corruption index*	92	4.36	0.51	3.54	5.94
International HIV Spending per PLHIV (USD)	92	419	457	1	2,137
Government revenue, excluding grants (% of GDP)	92	23%	9%	10%	57%
Gross Government Debt (% of GDP)	87	41%	23%	9%	143%
Government Health Expenditure (% of Government Expenditure)	91	11%	5%	2%	28%
Out-of-pocket health expenditure per capita (USD)	90	68	76	2	382
Non-drug cost per person retained on antiretroviral treatment (USD)	86	1,152	1,349	37	6,793
Public HIV Spending (% of Government Health Expenditure)	92	3%	8%	0%	69%

* This Worldwide Governance Indicator is rescaled to range from 2.5 to 7.5.

Extended Normative Approach

Our extended normative analysis considered how much additional resources could be generated if countries were to meet targets or benchmarks anchored in either fiscal capacity, minimum standards or optimal targets. We drew on the framework of domestic fiscal space sources above. In addition to forecasted economic growth, government revenue generation, and the prioritisation benchmarks used in a recent study (7), we included borrowing and incorporated new norms for the earmarked revenue category and efficiency gains. We used norms set by global/regional agreements, governing bodies or institutions, such as the International Monetary Fund (IMF). Where these were not available, we developed norms based on optimal levels from other countries as described below. All financing sources and measures are summarised in Table 6.2.

Compared to previous normative analyses (7, 13, 14), we included three additional components of fiscal space. First, we attempted to quantify the potential fiscal space from health-earmarked revenue sources, using the example of social health insurance. To estimate how much fiscal space may be generated from such a scheme, we assumed current out-of-pocket expenditures in excess of the WHO acceptable level of 20% of total health expenditure spent in the private sector, could be converted into social health insurance premia that would flow to the government health budget and be used for strategic purchasing (23). We also examined the fiscal space generated by an increased excise tax on alcohol (beer specifically), whereby the net additional revenue from increasing the tax from its current level to the West African Economic and Monetary Union's threshold of 50% (24) could be allocated to health, and proportionately to HIV.

Second, we constructed a simple measure of technical efficiency using the ratio of non-drug expenditures per person retained on ART to GDP per capita, and identified the best performing country among the 14 countries per income category (low-income, lower-middle-income, upper-middle-income). We then estimated logarithmic functions for each income category based on these best performers and the finding from a cross-country empirical analysis of ART unit costs that found that a doubling in per-capita GDP was associated with a 22% increase in non-drug ART unit costs (25). These functions served as an efficiency frontier to estimate each country's potential non-drug ART unit cost given its GDP per capita, and how much fiscal space would be generated if each country reached that benchmark in their HIV programme, thereby freeing up further resources to spend on HIV services. It is worth pointing out that we did not find an adequate cross-country measure of allocative efficiency between HIV programme areas, while this may be a key source of efficiency gains.

Finally, while previous analyses have implicitly assumed that less prioritisation of the HIV programme would reduce fiscal space for HIV improvement (7, 13), we explored the potential HIV gains from reprioritisation towards investments in other areas of spending (either in health systems, or in other sectors) that have been shown to improve HIV outcomes. To illustrate this potential, we used an exploratory cross-sectional econometric model for Prevention of Mother-to-Child HIV Transmission (PMTCT) screening (see Appendix 2 S12), which examines how much higher PMTCT screening coverage could be achieved if countries achieved the WHO minimum norm of having 2.3 health workers per 1000 population. We then estimated how much more a country would have had to spend in total on HIV to achieve that same increase. We applied that percentage increase to the public HIV spending figure, as a measure of potential savings to the HIV budget from investments by other health systems budgets. Put differently, by using the effects of human resource inputs and financial inputs on service coverage, we were able to calculate the monetary valuation of the effect of increasing the number of health workers to the norm, from the HIV budget holder's perspective. To illustrate the same potential for interventions outside the health sector (11), we took the example of how a reduction in undernourishment to the Millennium Development Goal (MDG) target, could improve HIV

service coverage – again using PMTCT screening coverage – and therefore free up space in the HIV budget (26).

Empirical Approach

To examine how domestic HIV spending in low and middle-income countries was associated with movements in different fiscal levers in the past, we constructed separate econometric regression models for each fiscal space source used in the extended normative approach, except the non-HIV efficiency sources that were estimated for illustrative purposes from a separate model described in Appendix 2.

Each of the regression models are specified as follows:

(1) $Y_j = \theta_i C_{ij} + \beta x + \varepsilon_j$

where Y_j, the dependent variable, is public HIV spending per person living with HIV (PLHIV) in country *j*; C_{ij} is a vector of covariates c_i with θ_i vector of mean coefficients; x is each explanatory variable (or fiscal space source) with β its mean coefficient; and ε_i is an error term. The dependent variable and independent variables with monetary values or proportions were transformed into natural logarithmic form, implying that the coefficients of the independent variables can be interpreted as elasticities, or measures of responsiveness (27).

Covariates were selected based on a previous study investigating the determinants of domestic HIV spending (15). These include disease burden (HIV prevalence), quality of governance (control of corruption), and national income level (GDP per capita). In addition, we include international HIV spending per PLHIV as a covariate, given the potential interaction and fungibility with public spending, as documented in the health expenditure literature (28). The year of the spending data was added as a time trend variable for the independent effect of changes in technology, medical practices and cost pressures (29). Finally, we included regional dummies to account for qualitative differences between UNAIDS regions.

We specified seven different models. In the first model, we included all the aforementioned covariates and the first theoretical source of fiscal space: economic growth, proxied by GDP per capita as the independent explanatory variable. In the seven successive models, we kept GDP per capita as a covariate and added variables for each theoretical source of fiscal space one by one (models 2 to 8). We would expect public HIV spending per PLHIV to be positively associated with GDP per capita, government revenue, government health and HIV prioritisation (7, 13, 20); but negatively associated with out-of-pocket health expenditures per capita (the inverse of the extent of risk pooling) (29). The relationship with government debt could be either positive or negative, depending on whether additional borrowing frees up other government resources for the HIV programme (13, 30). The relationship with the measure for technical efficiency (the non-drug cost per person retained on ART) is particularly ambiguous, as it will

depend on whether a more efficient ART programme attracts more government resources or less.

We used ordinary least squares estimation and performed standard diagnostic tests to validate the underlying assumptions. To explore the sensitivity of the findings and obtain additional insights into the variability of the effects, we used two additional estimation methods: quantile regression and neighbour matching fixed effects (31). The former is less sensitive to outliers and accommodates for the effects of the independent variables to vary over quantiles of the dependent variable. Indeed, it is likely that public HIV spending is more or less responsive to changes in fiscal policy at different levels of spending. In addition, it is possible that our models omit important variables (observable or unobservable) that are driving both fiscal policies and public HIV spending. For example, certain dimensions of governance may not be sufficiently captured in our measures. To take this possibility into account, we applied neighbour fixed effects modelling (31), which involves a matching exercise between neighbouring countries aimed at controlling for unobserved characteristics that are similar between neighbouring countries (see Appendix 2, section 4.2.3).

Comparing the two approaches

We compared the cumulative maximum public HIV spending per PLHIV under the first approach where all normative targets are met, to an empirical scenario based on past government responsiveness to changes in each fiscal lever using the coefficients (or elasticities) from the OLS models for each statistically significant source of financing. Finally, we estimated the financing gap by comparing both estimates to the average annual fiscal cost of delivering HIV services over the same period in a continued scale-up scenario, as modelled in a recent analysis (32).

Table 6.2 Fiscal space framework and measures used per source

Source	Indicator	Modelled target	HIV adjustment
Economic growth	GDP, constant $ *(IMF)*	Average forecasted annual growth (2014-2018)	
Improved government revenue generation	Government revenue, excluding grants, as % of GDP *(World Bank)*	25% *(McIntyre & Meheus, 2013)*	
Reprioritisation – of Health	General government health expenditure as % of Total government expenditure *(WHO)*	15% *(Abuja target)*	
– of HIV	Public HIV spending as % of Government health expenditure *(UNAIDS, WHO)*	0.5 x HIV DALYs as % of total DALYs *(IHME 2010 Global Burden of Disease data)*	
Government borrowing	Gross debt as % of GDP *(IMF)*	40% *(IMF 'sound' level)*	
Health-earmarked resources – Risk pooling mechanisms	Reduced out-of-pocket health expenditure per capita through contributory pooling mechanism *(WHO)*	20% *(WHO acceptable level)*	50% of spending in excess of threshold converted from private sector to government health resources; minus risk-pooling mechanism administration cost (of USD 1.77 per capita) then apportioned to HIV based on current ratio of total HIV spending to total health spending
– Innovative domestic financing	Increased revenues from increase in excise tax on alcohol (beer) *(WHO)*	50% *(West African Economic and Monetary Union threshold)*	Minus reduction in sales due to tax assuming -0.3 price elasticity deducted from total revenue; then apportioned as above
Efficiency gains – Treatment & care programme technical efficiency	Ratio of Non-drug treatment spending per person retained on ART to GDP per capita *(UNAIDS)*	Non-drug unit cost estimated from logarithmic production possibility frontier derived from most 'efficient' country with the minimum ratio by income group:16% (Zimbabwe) for LICs; 9% (Zambia) in Lower MICs; 15% (Botswana) in UMICs	Number of people receiving antiretroviral drugs (ARVs) adjusted by 12 month retention rate; Share of savings in total HIV treatment and care spending then applied to public HIV spending
– Health system technical efficiency gains for the PMTCT programme	Aggregate health personnel density *(WHO)*	2.3 per 1000 population *(WHO minimum level)*	Regression model of PMTCT screening coverage, with Nurse density, Proportion of undernourished in total population, HIV prevalence, GDP per capita, Total HIV spending per PLHIV, Adult female literacy, Urbanisation rate *(see Appendix 2 for details)*
– Non-health sector efficiency gains for the PMTCT programme	Proportion of undernourished People in the total population *(FAO)*	11.7% *(MDG1 target of halving 1990 level of 23.4% in developing countries)*	

6.3 Results

As presented in Table 6.3, annual public HIV spending in the 14 countries is currently estimated at USD 3.04 billion. Using the extended normative approach, we estimated that in the next five years an additional USD 120 million could be generated per year from economic growth, USD 79 million from improved revenue generation, USD 888 million from borrowing, USD 1.05 billion from increased health prioritisation, USD 1.68 billion from greater HIV prioritisation, USD 275 million from pooling out-of-pocket expenditures, USD 171 million from increased alcohol taxation, and USD 937 million from efficiency gains in the public HIV programme based on ART service efficiencies. Cumulatively, if all these fiscal levers were simultaneously leveraged, public HIV spending could reach USD 10.84 billion per year. In addition, investments in the health system to increase human resources to the recommended minimum would reduce the need for additional direct HIV expenditures of USD 418 million; while investments to reduce malnutrition could further save USD 653 million of direct HIV investment (see Appendix 2 S13-15).

The largest sources of fiscal space varied considerably between countries and income categories. For our selected low-income countries, a greater prioritisation of HIV in the health budget could mobilise substantial resources. For the lower-middle-income countries, a greater prioritisation of health in the national budget had the greatest potential in the medium-term. The next best option was borrowing, which was largely driven by Nigeria's low debt ratio. For the upper-middle-income countries, greater HIV prioritisation in the health budget and savings following a more efficient delivery of ART services were the top source of fiscal space. Within the five-year period, economic growth and better revenue generation would provide comparatively fewer resources across all countries. Interestingly, the potential HIV budget savings from non-HIV investments compared favourably with other sources, especially in low-income countries.

There was substantial variation in both fiscal space and the number of fiscal levers available across countries. For example, Lesotho and Malawi had few options to create substantial fiscal space, whereas Nigeria could capitalise on several options that could independently double its current expenditure.

The empirical models in Table 6.4 show how much fiscal space was generated for HIV in the past from changes in each fiscal lever. They indicate that the assumption that other fiscal levers remain unaffected when one fiscal lever is changed may overestimate the potential for additional financing. Our analysis of the determinants of past spending suggested that only higher GDP per capita (economic growth) may have led to a more than proportionate increase in public HIV spending, as a 1% increase in GDP per capita was associated with 1.09% increase in public HIV spending (model 1). This may indicate that HIV services were viewed in economic terms as 'luxury' services, which received larger shares of income as income grew - or were 'income elastic'. However, since this coefficient is not significantly greater than 1

(ranging from 0.94-1.24), public HIV spending could also have received a smaller or equal share of national income as it increased). The neighbour pair fixed effects model presented in Table 6.5, found a higher and more robust income elasticity (1.25), while the quantile regressions suggested more responsiveness among the lower spenders (typically the lower-income countries) and less among the bigger spenders (1.21 vs 0.75).

Conversely, countries with a 1% higher prioritisation of health in the national budget only spent 0.40% more on HIV, indicating that countries spent disproportionately less of their larger health budget on HIV services. The bigger spenders (75th percentile) were more responsive to this lever, while the lower spenders might not have been (Table 6.5). Looking more closely at the determinants of HIV prioritisation, we found that countries with a 1% higher health share in the government budget, allocated 0.74% less to HIV from the health budget (Appendix 2 S11). This suggested that countries that prioritised HIV more, did so despite or in compensation of lower government health spending. Model 7 in Table 6.4 seems to further corroborate this, as even a 1% increase in the share of HIV in the health budget was only associated with a 0.76% increase in HIV spending. This low level of responsiveness, or 'inelasticity', is robust to all estimation methods (Table 6.5).

Other fiscal levers did not seem to have had an impact on HIV expenditures to date according to the OLS estimation, but their signs were consistent with our expectations and all coefficients suggested an inelastic relationship (<1). The models had relatively high explanatory power, and the diagnostic tests did not indicate concerns around model specification or omitted variables.

That being said, we gained further insights from the alternative estimation methods we used to explore what these results were sensitive to. For example, another noteworthy difference is that after adjusting for unobserved characteristics that are similar among neighbouring countries, improved government revenue generation appeared to be significantly associated with public HIV spending, while health prioritisation was not. This suggests that governments that were better at collecting revenue were also more consistently able and willing to spend those resources on HIV.

Another finding worth highlighting is the repeatedly significant positive relationship between countries' levels of public and international HIV spending. A 10% increase in international spending was associated with a significant 1.0% to 4.0% increase in public HIV spending (Table 6.4). This may be linked to its significant positive relationship with government's prioritisation of HIV in the health budget (Appendix 2 S11).

If past behaviours of low and middle-income countries continue into the future, we found that fiscal space may only be realistically created from economic growth, greater health or HIV prioritisation. For these prioritisation measures, the resulting increase in public HIV expenditure would be less than has been assumed, and a larger share of health in the national budget and of HIV in the health budget have not been achieved simultaneously. Comparing the maximum

annual fiscal space estimates under the normative approach to the fiscal space estimates based on the responsiveness found in the OLS models, with only GDP per capita, health and HIV prioritisation being brought up to their forecasted levels or targets, we find between 4% and 80% less potential public finance in the selected countries (median 57% less) (see Figure 6.1).

When comparing both the normative and empirical estimates of fiscal space for HIV to the fiscal needs, we found that Malawi, Uganda, Zimbabwe, Tanzania, Mozambique, Lesotho and Zambia would not be able to fund their HIV programmes in either scenario. On the other hand, under the normative approach, Kenya, Nigeria, Ethiopia, and Swaziland could cover this cost in principle, but not under the empirical approach. In this case, only South Africa, Botswana and Namibia could meet this fiscal need under both scenarios.

Table 6.3 Potential medium-term sources of domestic financing (USD) in selected countries in sub-Saharan Africa based on the expanded normative approach

	Current Public HIV spending (USD)	Average Additional Public HIV Spending (2014-2018 annualised, USD)								Maximum potential Public HIV Spending (USD)	Average HIV savings from non-HIV spending (2014-18, annualized, USD)	
		Economic growth	Govt revenue generation	External borrowing	Reprioritisation		Health-earmarked sources		Technical efficiency gains		Expansion of HRH	Reduced undernourishment
					Health	HIV	Health risk-pooling mechanism	Alcohol tax	Reduced non-drug cost	ART unit		
Low-Income Countries												
Ethiopia	29,873,725	2,483,346	23,472,213	23,914,041	10,502,582	0	1,676,226	0	18,799,533	**218,672,382**	109,013,328	31,722,582
Malawi	2,076,376	148,797	0	0	0	28,452,963	0	11,280,604	0	**48,099,500**	5,917,374	1,046,868
Mozambique	13,833,586	1,286,161	1,009,317	0	9,729,293	39,293,813	0	n.a.	7,267,865	**163,100,675**	35,106,269	15,879,784
Uganda	42,372,003	3,376,698	36,680,242	4,424,621	19,824,309	0	44,342,876	0	34,919,679	**226,770,473**	26,116,695	47,835,568
Tanzania	7,292,938	598,900	3,175,056	0	3,433,372	70,781,762	5,357,016	n.a.	5,169,052	**253,765,981**	35,412,688	7,963,036
Zimbabwe	35,710,509	1,685,083	0	0	n.a.	10,623,961	n.a	n.a.	0	**52,795,374**	18,938,406	31,647,486
Lower-Middle-Income Countries												
Kenya	144,603,851	10,477,064	11,219,264	0	226,129,240	0	89,037,711	n.a.	92,154,809	**674,250,737**	152,310,361	116,208,273
Lesotho	50,694,268	3,057,221	0	0	1,817,686	0	0	n.a.	40,404,416	**102,101,635**	n.a.	n.a.
Nigeria	123,946,158	9,819,442	0	213,804,800	155,173,666	67,048,691	134,816,685	41,181,447	61,196,796	**1,678,586,031**	16,288,281	0
Swaziland	32,128,818	693,315	0	26,178,551	0	16,889,249	0	4,064,522	15,356,386	**114,058,678**	n.a.	n.a.
Zambia	16,350,025	1,278,110	3,114,290	7,027,191	0	68,248,827	0	n.a.	0	**217,804,380**	18,567,945	22,079,281
Upper-Middle-Income Countries												
Botswana	315,948,052	14,128,478	0	527,198,394	273,135,411	0	0	14,386,505	0	**1,779,276,710**	0	216,418,647
Namibia	181,203,580	8,983,056	0	85,723,694	14,961,072	0	0	n.a.	31,841,130	**362,037,531**	0	161,999,829
South Africa	2,040,790,395	61,494,978	0	0	337,351,516	1,378,692,629	0	99,860,577	629,861,977	**4,953,607,750**	0	0
Total LICs	131,159,138	9,578,984	64,336,828	28,338,662	43,489,557	149,152,499	51,376,118	11,280,604	66,156,129	**963,204,386**	230,504,760	136,095,325
Total Low MICs	367,723,120	25,325,153	14,333,555	247,010,542	383,120,593	152,186,768	223,854,396	45,245,969	209,112,407	**2,786,801,461**	187,166,586	138,287,554
Total UMICs	2,537,942,027	84,606,512	0	612,922,088	625,447,998	1,378,692,629	0	114,247,082	661,703,107	**7,094,921,991**	0	378,418,477
TOTAL	3,036,824,285	119,510,649	78,670,382	888,271,292	1,052,058,148	1,680,031,895	275,230,514	170,773,654	936,971,643	**10,844,927,838**	417,671,345	652,801,356

Note: All monetary figures are in 2014USD. Maximum potential public spending is a cumulative value if all the sources are increased simultaneously, which is why it is more than the sum of each source. To avoid double-counting, where revenue generation was increased to the norm and health reprioritised, we did not include the additional health-earmarked sources in this cumulative sum. LICs: Low-income countries; Lower MICs: Lower-middle-income countries; UMICs: Upper-middle-income countries.

Table 6.4 Regression analyses (OLS) of Public HIV spending per PLHIV (USD) by source of fiscal space

	Ordinary Least Squares Regression Models						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Control variables							
HIV prevalence	-0.172 (0.123)	-0.221* (0.128)	-0.191 (0.126)	-0.181 (0.124)	-0.158 (0.127)	-0.254** (0.124)	-0.782*** (0.084)
Control of corruption index	0.240 (0.250)	0.245 (0.249)	0.186 (0.263)	0.077 (0.265)	0.224 (0.255)	0.512** (0.249)	0.282** (0.142)
International HIV spending per PLHIV	0.212** (0.094)	0.214** (0.093)	0.198** (0.097)	0.190** (0.093)	0.202** (0.095)	0.132 (0.094)	0.101* (0.054)
Year of spending data	0.036 (0.087)	0.050 (0.088)	0.059 (0.088)	0.064 (0.087)	0.045 (0.090)	0.028 (0.084)	-0.036 (0.050)
Reference: West & Central Africa							
East & Southern Africa	0.328 (0.354)	0.375 (0.355)	0.484 (0.366)	0.396 (0.353)	0.286 (0.372)	0.185 (0.333)	0.108 (0.202)
Asia & Pacific region	0.019 (0.403)	0.088 (0.406)	-0.108 (0.408)	0.026 (0.399)	-0.034 (0.415)	-0.156 (0.387)	-0.040 (0.229)
Latin America region	1.310*** (0.428)	1.309*** (0.427)	1.350*** (0.425)	1.135*** (0.446)	1.374*** (0.438)	1.017** (0.429)	0.708*** (0.247)
Caribbean region	-0.359 (0.543)	-0.328 (0.541)	-0.243 (0.543)	-0.353 (0.537)	-0.368 (0.562)	-0.473 (0.503)	-0.123 (0.308)
Easter Europe & Central Asia region	0.687 (0.485)	0.521 (0.500)	0.663 (0.485)	0.706 (0.481)	0.764 (0.495)	0.408 (0.468)	0.345 (0.276)
North Africa & Middle East region	-0.586 (0.539)	-0.715 (0.547)	-0.245 (0.559)	-0.575 (0.536)	-0.493 (0.553)	-0.524 (0.551)	0.148 (0.311)
Sources of fiscal space (explanatory variables)							
GDP per capita	1.091*** (0.153)	1.007*** (0.166)	1.050*** (0.157)	1.116*** (0.153)	1.137*** (0.216)	1.017*** (0.149)	0.994*** (0.087)
Government revenue, excl. grants as % GDP		0.443 (0.350)					
Gross government debt as % GDP			-0.162 (0.207)				
Government Health Expenditure as % Total Government Expenditure				0.400* (0.251)			
Out-of-pocket health expenditure per capita					-0.071 (0.181)		
Non-drug cost per person on ART						0.105 (0.118)	
Public HIV spending as % of Government Health Expenditure							0.757*** (0.058)
Constant	-78.508 (175.606)	-107.211 (176.421)	-124.623 (176.942)	-134.622 (175.506)	-97.565 (180.588)	-64.140 (168.128)	68.346 (100.270)
Observations	92	92	87	91	90	86	92
R^2	0.733	0.739	0.743	0.743	0.733	0.785	0.915

For the regressions the dependent variable and independent variables with monetary values or proportions were transformed into natural logarithmic form. The numbers in the cells are regression coefficients (standard errors). Significance levels are denoted as * for p < 0.10, ** for p < 0.05, *** for p < 0.01.

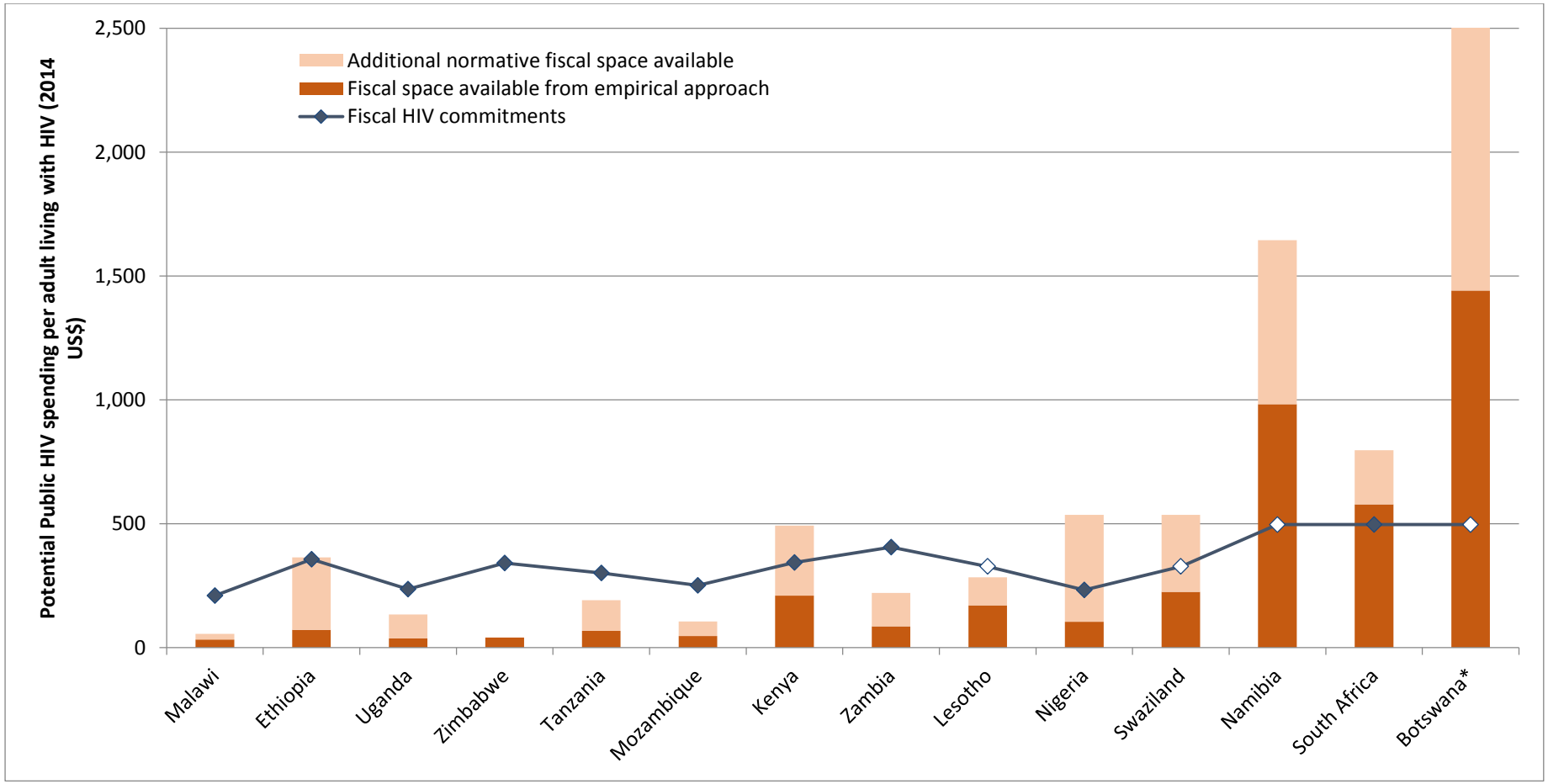
Each model tests the relationship with a different fiscal lever: (1) economic growth; (2) general revenue generation; (3) borrowing; (4) health prioritisation; (5) earmarked health revenue through risk-pooling scheme; (6) technical efficiency gains in the HIV programme based on ART programme efficiency; (7) HIV prioirtisation in health.

Table 6.5 Relationship between Public HIV spending per PLHIV and each fiscal lever with different estimation methods

	OLS	Quantile regressions			Neighbour(hood) models		
Fiscal space policy options		**25th percentile**	**50th percentile**	**75th percentile**	**Pair FE**	**Random pair FE**	**Neighbour-hood FE**
GDP per capita	1.091*** (0.153)	1.207*** (0.290)	1.102*** (0.183)	0.754*** (0.172)	1.168*** (0.174)	1.190*** (0.170)	1.246*** (0.150)
Government revenue, excl. grants as % GDP	0.443 (0.350)	0.312 (0.677)	0.242 (0.452)	0.486 (0.411)	0.850** (0.421)	0.845** (0.355)	0.825** (0.395)
Gross government debt as % GDP	-0.162 (0.207)	-0.065 (0.301)	-0.022 (0.358)	-0.074 (0.436)	-0.0758 (0.194)	-0.00471 (0.162)	-0.145 (0.182)
Government Health Expenditure as % Government Expenditure	0.400* (0.251)	0.189 (0.466)	0.419*** (0.337)	0.675*** (0.223)	0.199 (0.206)	0.284 (0.222)	0.229 (0.197)
Out-of-pocket health expenditure per capita	-0.071 (0.181)	-0.002 (0.332)	0.035 (0.220)	-0.144 (0.197)	-0.157 (0.165)	-0.107 (0.159)	-0.107 (0.168)
Non-drug cost per person on ART	0.105 (0.118)	0.045 (0.165)	-0.024 (0.166)	0.146 (0.127)	0.182 (0.127)	0.124 (0.108)	0.233** (0.116)
Public HIV spending as % of GHE	0.757*** (0.058)	0.851*** (0.068)	0.783*** (0.074)	0.812*** (0.088)	0.715*** (0.111)	0.688*** (0.117)	0.758*** (0.0767)

*The numbers in the cells are regression coefficients (standard errors). Significance levels are denoted as * for p < 0.10, ** for p < 0.05, *** for p < 0.01.*

Figure 6.1 Comparing the potential fiscal space for HIV from the extended normative approach to the empirical approach



* Botswana's additional space extends beyond the figure to USD 5,270, but was capped for legibility. Note: Fiscal commitments are average estimates over the same period from Hontelez et al (2016), except for Botswana, Namibia, Swaziland and Lesotho. For these countries we use averages from the countries in the same income categories. The normative estimate of potential public HIV spending excludes the potential savings from non-HIV spending.

6.4 Discussion

Our analysis suggests that the most HIV-affected lower-income countries in sub-Saharan Africa will not be able to generate sufficient domestic public resources in the medium-term, even if they take very bold measures to improve revenue generation, reallocate resources and maximise efficiency in line with their economic capacity. The shortfall between the optimistic normative estimate of potential financing and recent conservative estimates of financial obligations (with continued scale-up) remains considerable (32). Some of the lower-middle income countries could cover these costs in principle if they would adopt normative targets and tap more innovative fiscal levers. However, when past HIV financing behaviour (which may be rational) is taken into account, even they could not pay for their HIV programmes. Only the upper-middle income countries could potentially shoulder the fiscal costs of their responses in the near future. Our findings therefore support the broad global policy response to increasingly target international financing.

Our normative estimates of fiscal space are substantially higher than previous studies, because we include a more comprehensive (but still non-exhaustive) set of fiscal policy options, including some unconventional ones. This provides an optimistic picture, with significant effort required to realise some of this potential. We consider borrowing as a serious policy option; unpack and quantify some health-earmarked sources; as well as efficiency gains from within and beyond the HIV programme. When comparing the same sources, we generally find similar potential as the most recent study by Resch and colleagues (2015), although our estimates of fiscal space from economic growth and general revenue generation tend to be somewhat lower, possibly due to differences in data sources.

When we constrain our estimates by the empirical models of which levers have been related to public HIV spending in the past, they become lower than previous estimates. This approach highlights that achieving various norms/benchmarks is not likely to automatically translate into a real proportionate increase in HIV spending; in part due to the interaction between different fiscal policies. Therefore, focusing on reprioritising resources towards HIV and/or health alone, based on targets that have already proven to be politically challenging – may end up yielding less additional finance than anticipated.

It should be noted that our findings have several limitations. First, the quality of HIV spending data is weak. They may partly reflect spending where government is the agent rather than the source; capture disbursements rather than expenditures; and identify only HIV-labelled expenditures rather than overall expenditures for HIV. Secondly, we implicitly assume an immediate policy decision, no transaction costs and the absorptive capacity to implement fiscal targets (13). This is unlikely, particularly in areas like converting out-of-pocket expenditures into social health insurance premia, and hence we may overestimate the short-term potential from these sources. Similarly, although our empirical analysis was designed to incorporate the uncertainty around adjustments between fiscal policies, we have not incorporated the

uncertainty around the feasibility of achieving each norm. Some of the 'global' norms we used are quite conservative, such as economic growth and government revenue generation (12), whereas others are considerably more optimistic, like the Abuja target, or the share of out-of-pocket expenditures in total health expenditures. Still, there are countries among the 14 that achieved or surpassed each one of them.

A third limitation stems from relying on global analyses to draw conclusions for the sub-Saharan African sub-group, and past spending data to predict future spending. Indeed, it is reasonable to expect that the 14 most HIV-affected countries are qualitatively different from other low and middle-income countries, just as governments may make decisions differently going forward, especially if donors start changing their financing patterns (33, 34).

Finally, an important limitation in our empirical models is a potential endogeneity bias from our cross-sectional dataset. Although we used similar methods adopted in previous studies on the determinants of HIV and health expenditures (15, 27, 29, 35)- albeit for panel datasets - there is a risk when making causal inferences. We applied the neighbour fixed effects approach (31) to address the potential omitted variable bias, but neither estimation method addresses the potential bi-directionality between certain explanatory variables and public HIV spending. We considered this bias for each of the variables of interest. Where they may influence our estimates, it is likely to be by attenuating the impact of fiscal adjustments and overestimating coefficients. This would imply that our adjusted 'real world' estimates are still overestimates of the real fiscal policy effect on pubic HIV spending, but they would be closer than current normative estimates. The only exception would be GDP per capita, where we find greater responsiveness, but existing evidence does not support such macroeconomic impacts of HIV (36), even in high burden countries. The other variables of interest with a more important potential bi-directionality bias that could affect our findings are out-of-pocket health expenditures and the non-drug cost per person retained on ART. For both measures, the insignificant relationships we found do not rule out the existence of a relationship in either direction, and their exclusion from the empirical estimates may underestimate their potential.

Despite these limitations, our findings have some clear specific policy implications. Our empirical analysis suggests that governments have not used many of their domestic fiscal levers to increase HIV allocations. Country-level consultations indicate that domestic resource mobilisation has not been a priority in certain countries, given the availability of large external HIV funds and varying perceptions as to their likely decline (37). This could further explain why increasing the tax base was not consistently associated with past public HIV spending, as external HIV financing may have been easier for governments to mobilise.

Only economic growth, health and HIV prioritisation appear to have consistently influenced national levels of HIV expenditure. Strong economic growth in Africa is being hailed as a major source of domestic financing, but although we find that public HIV spending is very responsive to income (similarly to health expenditure (29, 35)), the magnitude of the increase from this

source alone is relatively small in the medium-term (30). Nonetheless, it represents a relatively reliable source that could sustain and multiply the impact of other measures in the long run. With strong political will, it may also be used more proactively to ring-fence resources for HIV services through a more than proportionate allocation formula, where desirable.

Countries could generate significant resources by reprioritising health in the general budget and HIV in the health budget (7), even though their independent and joint potential may have been overestimated to date (38). Moreover, greater HIV reprioritisation could risk crowding out other areas of health investment (12), although the evidence on this is mixed (39). It may be particularly difficult to further prioritise HIV in contexts where external financing is declining, without a simultaneous increase in other fiscal space sources, as our empirical models suggest that international financing for HIV may have indirectly contributed to greater HIV prioritisation in health, through some crowding-in effect. This contrasts with previous studies that find evidence of fungibility in the health sector more generally, whereby increases in development assistance for health channelled through governments have been associated with reductions in public spending on health from public sources (28, 35, 40). Even though it suggests care has to be taken to ensure appropriate co-financing arrangements, this could bode well for future agreements between governments and donors, such as the Global Fund's counterpart financing requirements or the PEPFAR partnership frameworks. However, there may be external explanations for this finding. Alternative interpretations include that much of HIV-related aid may have been channelled to NGOs and therefore not displaced government spending (28); or aid may be given to countries that already prioritise HIV more and have better governance, as we find in our analysis. This may also be a measurement error, where some reported public spending may include external aid channelled through government budgets.

In terms of the new areas of financing identified, our analysis suggests that several are worth further exploration. Concessional borrowing has potential in principle, assuming the returns to these investments outweigh the costs of borrowing. Yet, this has not been a politically attractive option for direct HIV spending or for freeing up government resources. This could have several reasons, including that governments may not view HIV spending as an investment with financial returns, despite the 15:1 return estimated by UNAIDS (2). Moreover, this ability to borrow could also be a reflection of recent debt relief in some countries resulting in low debt stocks, rather than sound debt management. Yet, given the magnitude of future HIV treatment obligations, the case could potentially be made for more concessional HIV borrowing, especially in resource-rich countries (41). Further macroeconomic modelling is required to estimate the dynamic feedback of HIV investments on fiscal space.

We also find substantial potential from earmarked sources for health, suggesting that those focusing on HIV have a strong mutual interest with those working on general health sector financing. Converting high levels of out-of-pocket expenditure into stable and non-regressive public revenue through social health insurance could mobilise considerable resources for HIV, and other health programmes, in Kenya, Nigeria and Uganda, for example. But the institutional

reforms required would be substantial and time-consuming. The government of Kenya has recognised this potential and decided to increase premia for the National Hospital Insurance Fund by 25% to raise domestic resources for HIV and non-communicable disease by a projected USD 120 million over 5 years (37). This is considerably less than our estimated USD 89 million per year, but is likely a more realistic estimate of gradual revenue generation through this mechanism. Earmarked increases in alcohol taxes could also generate resources, in addition to their expected double dividend of reducing HIV transmission and improving treatment efficacy (42, 43). Kenya and Benin have also considered HIV-earmarked taxes on airline tickets and mobile phone usage, respectively (37). However, any earmarking may reduce fiscal flexibility and allocative efficiency in public finance more broadly (23, 38); and may not be acceptable to ministries of finance. Moreover, it is quite likely that increased revenues from HIV-earmarked sources may in practice be accompanied by a reduction in allocations from general government revenue to HIV (12, 21, 38). In the extreme case of Kazakhstan, for example, following the introduction of a payroll tax earmarked for health, the subsequent general tax allocation to health reduced by more than the additional payroll tax, leading to a net reduction in health resources (30). Such mechanisms therefore might not generate any additional resources in the absence of credible commitment mechanisms.

Our analysis confirms the potential of technical efficiency gains; and supports the global policy emphasis on improving HIV programme efficiency for a sustained HIV response. Our estimates for South Africa, for example, suggest that there could be more to gain from the latter than from a greater prioritisation of health. However, the empirical data does not confirm our input-oriented measure of technical efficiency as a determinant of past public HIV spending. This may be because higher unit costs can influence spending in two opposite ways: by increasing spending to get the same output, or decreasing government's willingness to allocate resources to an inefficient programme. Also, this measure does not sufficiently capture price differentials or site-level heterogeneity. Nonetheless, it was expected to broadly reflect in aggregate terms the relative room for efficiency improvements, and interestingly, our normative estimates of potential efficiency gains (29% of current spending) – are more conservative than recent estimates using more sophisticated Data Envelopment Analysis techniques (53%) (16, 44). Our results are sensitive to which country is considered the best performer, particularly for the upper-middle-income country category, which is not surprising given the large unexplained variation in ART unit costs found in most empirical studies (45). Still, further research is needed to develop country-level measures of programme efficiency and understand its determinants.

For low-income countries, we found substantial gains from more effective complementary investments in health systems and social development. In these highly resource-constrained settings, the opportunity cost of increased HIV financing may be particularly high and synergistic investments all the more important. Our findings cautiously suggest that the HIV budget holder could see financial value in contributing to human resource expansion or reduced undernourishment, to avert direct HIV expenditures. This does not necessarily mean that they

should do so – the cost of this investment would first need to be determined and the net benefit of the investment established. Effective fiscal space would only be created if the investment required was more efficient than a direct investment in HIV services. However, given that both these investments have wider benefits than HIV alone, a co-financing approach that seeks to maximise HIV and other outcomes may be considered (12, 26). Some argue that the HIV sector has made only marginal short-term investments in health system complements that could be reaching their limits (46). It may be more rational for HIV budget holders to consider co-investing in these binding constraints. However, more research is needed in this area to explore which non-HIV investments could contribute most to the efficiency of HIV programmes and what institutional mechanisms could incentivise cross-sectoral and cross-disease governance and financing.

In conclusion, we present a more realistic, but still optimistic picture of improved domestic financing for HIV that will require the HIV community to engage with broader public finance and social development agendas. International funders can support this effort with a more coherent engagement across health and social development investments, a continued focus on efficiency, and a longer term approach to co-financing national HIV responses within broader health financing frameworks. With the ongoing dialogue on how to finance the sustainable development goals, it will be important that those working in HIV join the call for increased health prioritisation in the context of universal health coverage, and work to identify tailored country-specific approaches to proactively leverage broader development investments. This will be central to expanding access to HIV prevention and treatment in a way that is sustainable and in line with the post-2015 development agenda.

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SECTION A – Student Details

Student	Michelle Jeanette Sayi Remme
Principal Supervisor	Prof Anna Vassall
Thesis Title	Cross-sectoral co-financing: Taking a multi-payer perspective in the financing and economic evaluation of structural HIV interventions

If the Research Paper has previously been published please complete Section B, if not please move to Section C

SECTION B – Paper already published

Where was the work published?			
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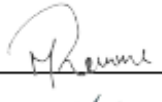
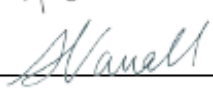
SECTION C – Prepared for publication, but not yet published

Where is the work intended to be published?	Journal of the International AIDS Society
Please list the paper's authors in the intended authorship order:	Michelle Remme, Mariana Siapka, Suneetha Kadiyala, Zindoga Mukandavire, Sandra I. McCoy, Fatiha Terki, Saskia de Pee, Anna Vassall
Stage of publication	**Submitted**

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	I was the lead author of this paper and conceptualised it with MS and AV. ZM and SK provided guidance. I designed and conducted the analysis. MS supported with the literature review and the model coding. I drafted the full manuscript and made
	revisions based on comments from AV, ZM, SIM, SK and SP.

Student Signature:  **Date:** 23/10/2017

Supervisor Signature:  **Date:** 29/10/2017

CHAPTER 7 Economic Returns to Investing in a Food-Based Intervention for People living with HIV Initiating Antiretroviral Therapy in East and Southern Africa

7.1 Introduction

The international community has embraced an ambitious global agenda to achieve 17 wide-ranging Sustainable Development Goals (SDGs) and their 179 targets by 2030 (1). This includes ending the AIDS epidemic as a public health threat, and much of the focus in the global HIV response is currently on reaching the 90-90-90 targets by 2020 (i.e. to ensure that 90% of all people living with HIV (PLHIV) get diagnosed, 90% of them are on treatment, and 90% of those on treatment achieve viral suppression) (2). However, there are serious challenges along the HIV treatment and care cascade, with only 54% of PLHIV knowing their status, globally, and 22% of those being lost-to-follow-up before even initiating treatment (3). Retention in care and adherence to antiretroviral therapy (ART) are also major concerns. Recent estimates from multi-country cohorts of ART patients indicate that 30-35% of patients are no longer in care 3 years after initiation (4). In Southern Africa, this attrition rate increases further to over half of PLHIV being out of care 5 years post-initiation (3). Although viral suppression is the ultimate goal of ART, both to halt disease progression and reduce onward transmission, only 45% of adults that start treatment are virally suppressed 36 months after initiation (3).

Clearly, the potential of ART to improve the lives of PLHIV and prevent new infections is not being fully realised, and the risk of resistance to antiretroviral drugs is further increased by patients' disengagement from care and sub-optimal adherence (3). The optimism around a universal test-and-treat strategy to reverse the epidemic has been dampened by recent evidence showing that even when home-based HIV testing is provided, followed by an immediate offer of ART for those who are HIV-positive, linkage to care and ART uptake have remained below expectation (5). This has underscored the limits of biomedical interventions alone and further pointed to the importance of structural drivers for HIV service uptake, treatment adherence and onward transmission (6, 7).

Food insecurity has been identified as a key barrier to retention and adherence in several settings (8, 9). This can be explained by a nutritional pathway, whereby food insecurity can exacerbate ART side effects; a mental health pathway, where food insecurity compounds patients' anxiety around initiating ART and the expected increase in appetite; and a behavioural pathway, through which food-insecure patients cannot adhere to their treatment regimen or

clinic appointments due to competing demands on their resources (9, 10). Even before starting ART, food insufficiency can translate into accelerated weight loss and immunosuppression (11). In addition, undernutrition significantly increases the risk of mortality among ART initiates (12-15), and weight gain immediately after ART initiation is an important predictor of long-term survival among those with a low Body Mass Index (BMI) (16, 17).

The significant geographical overlap between food insecurity and HIV disease burdens, as well as the complex bidirectional relationship between HIV treatment outcomes, nutrition and food security calls for integrated strategies (18, 19). While ART alone can have dramatic benefits for patients' nutrition and household food security, the outcomes of these treatment programmes can also be jeopardised by undernutrition and food insecurity (20, 21).

Existing evidence suggests that the most promising complementary food-based interventions for HIV treatment and prevention are in the form of conditional nutritional support to people initiating ART (22). Food supplementation has been found to improve adherence to treatment and reduce attrition (23-28), certain combinations of multiple micronutrient supplementation for pregnant mothers can confer clinical benefits for the mother-infant pair in the absence of ART, although they have not been found to reduce vertical transmission (29-31). There is limited but growing evidence on the potential HIV impact of non-food economic interventions targeted at food-insecure HIV-negative and HIV-positive populations, including cash transfers and economic strengthening interventions (19, 32, 33). However, most of these interventions have not been evaluated from an economic perspective, and their value for money remains unclear.

Flat-lining international HIV financing, coupled with the many competing development priorities in the SDGs, has heightened the need for prioritised investment approaches (34, 35). Decision-makers are having to strike a balance between allocating HIV resources to expand access to ART alone, or to add on adherence-enhancing interventions to prevent leaks in the cascade (36-38). Ensuring effective HIV prevention, care and treatment may require moving away from a siloed prioritisation approach to a more integrated multi-sectoral approach. This study aims to assess the costs, outcomes and value for money of a food and nutrition intervention, both for HIV and broader development impact.

7.2 Methods

Study design

We assessed the cost-effectiveness of investing HIV resources in an add-on food support component targeting food-insecure patients initiating ART. We used a Markov model to estimate the costs and outcomes of providing food assistance to these patients during their first 6 months on ART, compared to a 'standard of care' base case where patients received ART without food support, in five countries in East and Southern Africa. We took both a health care

provider perspective, and a broader multi-sectoral perspective to capture the non-health consequences of the intervention, in line with recent guidance (39, 40). This involved modelling three interventions cases: the first considered the health care consequences on the cohort alone, the second considered the cohort and partners, and the third factored in health and non-health consequences. The primary model outcomes were a cost per Disability-Adjusted Life Year (DALY) averted, and a benefit-cost ratio (BCR). The time horizon of the study was the lifetime of the cohort of patients initiating ART, i.e. until the last patient died.

Study setting and timeframe

To investigate the potential return on investment from implementing this food-based intervention in different settings, we selected five of the UNAIDS 'fast-track' countries in sub-Saharan Africa with different typologies in terms of HIV burden, food insecurity and income levels, namely Tanzania, Zambia, Ethiopia, Lesotho and South Africa. In addition to the lifetime timeframe, we analysed results after 5 and 15 years to reflect the UNAIDS 'window of opportunity' between 2016-2020 to frontload investments and control the epidemic, as well as the global commitment to ending AIDS as a public health threat by 2030 (2).

HIV models

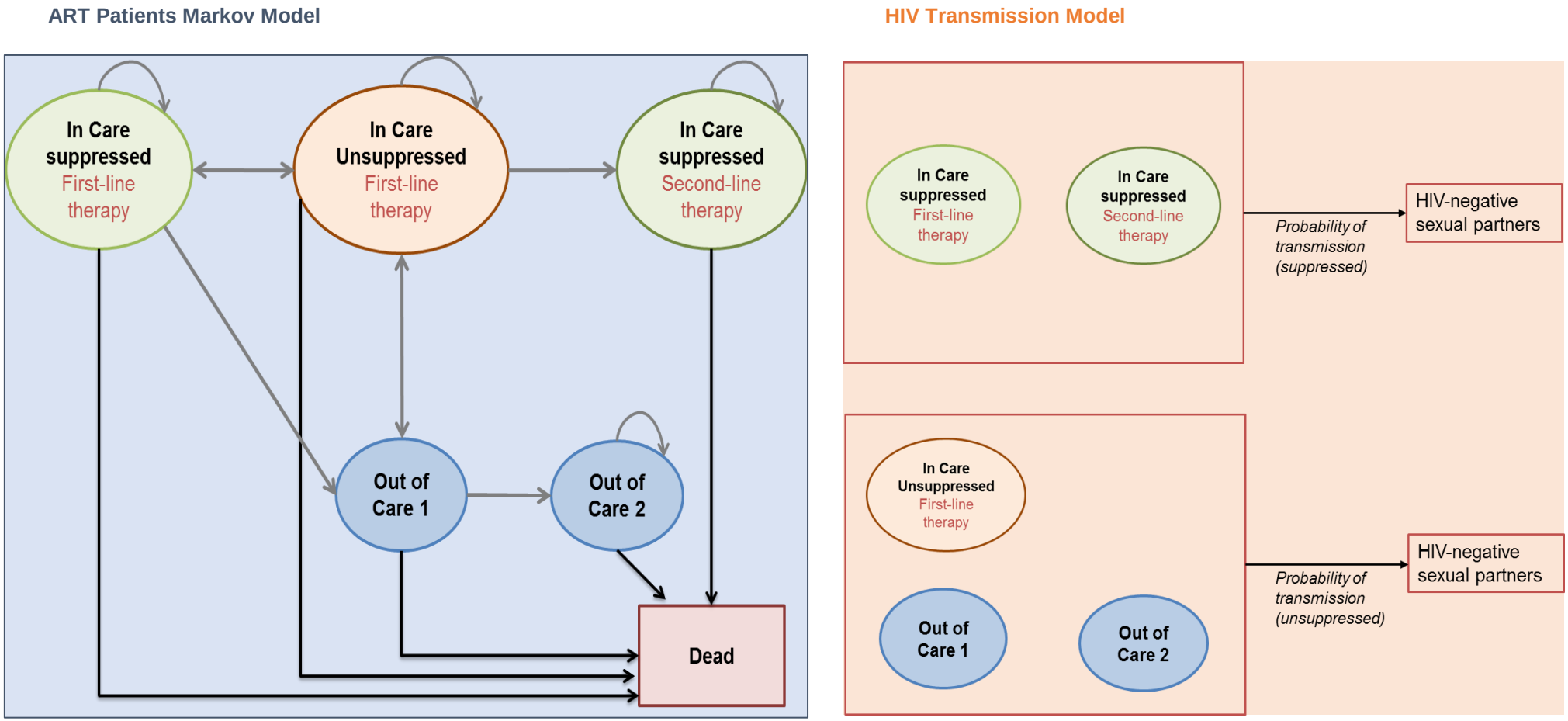
We developed a Markov model for ART patients to follow a hypothetical cohort of individuals as they moved along a linear clinical pathway, based on simple Markov chains. Markov modelling is particularly well-suited to chronic diseases, and has been extensively used to evaluate the cost-effectiveness of treatment options for heart disease, asthma, cancers, and also HIV care (41-43). Disease progression can be divided into separate health states, with transition probabilities that determine individuals' movements between these states for each time period (or 'Markov' cycle) (41). Unit costs and health utility (or disutility) are assigned to each state, and by running the model over several cycles, it is possible to estimate the long-term costs and health outcomes with and without an intervention.

Our model consisted of 6 states through which individuals could progress: three states in ART care; two states out of care; and an absorbing 'dead' state (see Figure 7.1). All individuals entered the model and started first-line ART at time t_0. By the end of the first cycle, they were either in care and virally suppressed; in care but unsuppressed; out of care; or dead. Those who were on first-line therapy but unsuppressed could either remain unsuppressed, achieve viral suppression, die, or progress to second-line therapy in the next cycle. We made several simplifying assumptions. First, once in second-line ART care, this small group of patients (44) were virally suppressed and could only remain in that state or progress to death. Second, individuals who had disengaged from care for one cycle could return into first-line ART care, but were expected to be unsuppressed for at least one cycle if they did. Third, once patients progressed to a second cycle out of care, they could not transition back, and either remained out of care or died.

Each cycle accounted for a 6-month period, given the higher rates of mortality and loss to follow up (LTFU) in the first 6 and 12 months of ART. We followed a cohort of 1,000 food-insecure individuals initiating ART, until they all died.

The ART Patients model was linked to a simple static HIV transmission model to estimate the number of secondary HIV infections from this cohort of patients to their sero-negative sexual partners. We used risk equations to estimate the probability of transmission among uninfected partners per cycle until the cohort turned 60 years old. Separate probabilities were calculated for individuals who mixed with the patients in virally suppressed states, and those in unsuppressed states (see Figure 7.1). The model equations and further details are provided in Appendix 3.

Figure 7.1 Model diagram



Base case

In the base case, we modelled the progression of a cohort of patients initiating ART at the age of 35, in each country, without the intervention. Model input parameters are summarised in Table 7.1. State transition probabilities were sourced from the literature where possible. In the absence of country-specific data, we used the same transition probabilities derived from systematic reviews from the region or from ART cohorts from low and middle-income countries (4, 12, 45). We incorporated time-dependent transition probabilities to reflect heightened risk of LTFU and AIDS-related mortality in the first 6 and 12 months on ART. Also, given the known misclassification of mortality as LTFU for people in ART care (46, 47), we adjusted these mortality parameters upward by a correction factor from the literature (14, 48). All-cause mortality rates were also time-dependent and adjusted for every 5-year period, based on the WHO life tables for each country. All other transition probabilities were kept the same from the third cycle onward, except for adjustments to account for increasing mortality as the cohort aged.

We made assumptions about several transition probabilities due to lack of data. These probabilities were then adjusted to calibrate the model outcomes to the average rates of: (i) retention in care, (ii) on-treatment viral suppression, and (iii) mortality on ART, as reported by multi-country ART cohort sites either in sub-Saharan Africa or low and middle-income countries, at various time points between 6 and 60 months post-initiation (3, 4, 49, 50). This is likely to have generated more optimistic outcomes than may be expected among the vulnerable food-insecure patients the intervention would target.

Intervention case 1 - Health care cohort perspective

In the first intervention scenario, we modelled the intervention's health care impact on the cohort alone. The intervention modelled is a common standard food assistance intervention, as delivered by the World Food Programme and other organisations, which typically involves the provision of a monthly food ration, consisting of cereals, legumes and sometimes vegetable oil (22). The food basket is provided during the first 6 months of ART, and can be conditional on clinic attendance. Eligibility is assessed during an initial screening, using a household food security assessment questionnaire like the Household Hunger Scale (28), to identify individuals in moderately or severely food-insecure households. Clinically malnourished patients, with a Body Mass Index (BMI) below 18.5, are referred to supplementary feeding with fortified foods where available, and may additionally receive food assistance (22).

We identified eight studies evaluating the effectiveness of food assistance on HIV treatment outcomes among adults in low and middle-income countries, including those from a previous review (22) (see appendix 3 Table S1). Most studies were conducted in sub-Saharan Africa, including one multi-country study, and two were from Central America and the Caribbean. The studies were of mixed quality: only two had either an individually or cluster randomised design

(28, 51), and two were quasi-experimental (24, 52). The remaining four evaluations lacked a comparable control group (23, 25-27). While seven studies had an ART adherence outcome, only two considered attrition outcomes (23, 53). None of the studies explored the effect of improved adherence on HIV transmission. All but one found a positive effect of food assistance on adherence or reduced attrition (52).

The Tanzanian 'Afya study' was the only randomised controlled trial identified that assessed adherence, attrition and costs. We therefore modelled its direct effects in our main analysis. However, we explored the sensitivity of our results to the range of effectiveness data from the other studies (see Table 7.1) (23, 24).

Adherence was defined as a Medication Possession Ratio (MPR) of at least 95% at 6 months after initiation, which is the proportion of days within a specific period that an individual is in possession of at least one ART dose (54). The intervention risk ratio for this adherence measure was 1.25 (95% CI: 1.07-1.45) (28). We then used data from a meta-analysis that found a pooled odds ratio for virologic failure with optimal adherence compared to suboptimal adherence of 0.34 (95% CI: 0.26–0.44), suggesting that individuals with optimal adherence were 66% more likely to be virally suppressed (55). This was used to alter the transition probability to remaining in care and suppressed in the first cycle from 0.685 to 0.797, in our Markov model.

Attrition was defined as the proportion of patients initiating ART that died or were lost to follow-up, i.e. had not attended a scheduled visit for at least 90 days (excluding clinic transfers) (23, 28). We applied the effect of food assistance on reducing LTFU in the first 6 months of ART from the Afya study (RR=0.14, 95% CI: 0.05-0.38) (28). Both the probability of disengaging from care and dying in the first 6-month cycle were therefore adjusted in the intervention scenario from 0.114 to 0.016, and from 0.066 to 0.009 respectively.

Intervention case 2 - Health care perspective with HIV transmission

In this broader health care perspective, we also considered the secondary health consequences of the intervention on the partners of the patient cohort. We ran the HIV transmission model to estimate the impact of the 96% reduced risk of HIV transmission to a sero-negative sexual partner when a patient has achieved viral suppression (56). We sourced country-specific sexual behaviour data from Spectrum (a publicly available modelling tool used by UNAIDS) (57) to parameterise the model (see Table 7.1).

Intervention case 3 - Multi-sectoral perspective

In this perspective, we sought to capture any non-health consequences of the intervention. However, the evidence base on the broader welfare effects of food assistance (e.g. on labour productivity, nutrition) is scant (58), and we only identified one recent study from Honduras with a demonstrated effect of food assistance on severe food insecurity among established ART

patients (59). We therefore explored the implications of this potential effect on food security alone, and modelled what would happen if part of the incremental costs of the intervention were covered by a social protection budget based on this benefit (60). The effect modelled is a 24% reduction in severe household food insecurity after 6 months of food assistance (RR= 0.76, 95% CI 0.60-0.97) (59).

Economic Costs

Costs for each state in the model were sourced from empirical provider costing studies, identified from a systematic review(61) and studies with large samples of facilities. All costs were extrapolated to the 5 selected countries following a log GDP per capita adjustment for non-tradeables (as the best empirical fit)(62), whereas tradeable goods (namely drugs) were kept fixed. All costs were then inflated to USD 2015 using the US GDP deflators.

Country-specific first-line ART costs per person were calculated as a median across three studies, including 8 sub-Saharan African countries (63-65). This was adjusted with a mark-up for those in care but unsuppressed who require additional facility visits and tests (66). Second-line ART costs per person were extrapolated from South Africa, as above (67). Individuals that had disengaged from care incurred other health care costs, namely hospitalisation (68), while those who died first incurred costs related to end-of-life palliative care (69). We conservatively did not consider any additional costs of re-entering care.

The direct intervention provider costs were estimated from the Tanzanian Afya trial at USD198 per client for 6 months (70). The latter was implemented from November 2013 to February 2016 in three study sites in Shinyanga region. For this economic costing, data were collected retrospectively, following an ingredients approach and excluding research costs. Input prices were obtained from the project, health facilities, regional office records, and local suppliers. Capital costs were annuitized using standard useful life years, and discounted at 3%. All project overhead and intervention costs were allocated based on estimated use by activity, using step-down allocation. Staff time allocation between activities was estimated from a combination of self-assessments, interviews and time sheets, and used to allocate overheads. The relative numbers of beneficiaries receiving food baskets was used to allocate the support costs. Costs were estimated in Tanzanian Shillings and then converted into 2015 USD. Further details are provided in Appendix 3.

Given the intervention's small-scale delivery model and its relatively small locally-procured food basket, it may be considerably less costly but potentially difficult to replicate at a larger scale. We therefore also consider much higher cost estimates from a World Food Programme intervention in Mozambique in a sensitivity analysis (71).

Valuation, Cost-effectiveness and Economic Returns

Incremental cost-effectiveness ratios (ICER) were estimated as a cost per (HIV) DALY averted – a standard measure of value for money used in HIV and health intervention prioritisation (72). To estimate DALYs, we used common disability weights for HIV sequelae (73). For individuals who were in care but unsuppressed, we used the disability weight for symptomatic HIV pre-AIDS (73). DALYs averted by preventing new HIV infections were calculated using new standard formulae, without age-weighting (74), and assuming full ART coverage after the asymptomatic and pre-AIDS stages. Given that costs were discounted at 3%, we applied the same rate to DALYs in the main analysis, but explored a no-discounting approach in a sensitivity analysis (75).

In addition, benefit-cost ratios were derived by monetising each DALY at USD1,000 to provide an indication of the potential economic returns of investing in this intervention (76).

There are currently no empirical country-specific cost-effectiveness thresholds that reflect real opportunity costs to the HIV or health budget (77), and that can be used to determine whether an intervention is cost-effective. We tentatively compare the ICER to the thresholds estimated for several low and middle-income countries by extrapolating an empirical analysis from the UK, which is around 0.5 times a country's GDP per capita (78). If food assistance could avert a DALY at a cost below this, it would be deemed a cost-effective HIV investment.

For the multi-sectoral perspective, the non-health outcome was valued in terms of how much the corresponding sector budget would be willing to pay for it. Based on studies on the cost and impact of a cash transfer programme on severe food insecurity in Zambia, we estimated the social protection sector's or payer's revealed willingness-to-pay per averted case of severe household food insecurity (see Table 7.1) (79, 80). This estimate of the opportunity cost was then multiplied by the number of individuals that would be expected to not be severely food-insecure during the 6-months of the intervention. This amount was then deducted from the HIV payer's total cost in the first cycle (60).

Sensitivity Analysis

Univariate and probabilistic sensitivity analyses (PSA) were conducted to explore the sensitivity of the results to various parameter and distributional assumptions. For the PSA, we specified parameter distributions and then propagated the uncertainty throughout the model using second order Monte Carlo simulations, which were run 1,000 times. Given the uncertainty around the value of the cost-effectiveness threshold (78, 81), we also produced cost-effectiveness acceptability curves to illustrate the probability that this intervention would be cost-effective at different thresholds.

Budget, health and food security impact of implementing the intervention over the next 5 years

We used the Spectrum model to estimate the number of people initiating ART per year from 2016 to 2020 (57), and derived an estimate of severely food-insecure patients who would be eligible for food assistance. We then ran these cohorts of patients initiating ART over the next 5 years through the model and estimated the incremental national costs, DALYs, and cases of severe food insecurity averted until 2030.

Table 7.1 Key assumptions and Model Parameters

Parameter	Tanzania	Zambia	Ethiopia	Lesotho	South Africa	Distribution	Source(s)
Cohort characteristics							
Cohort size			1,000			n.a.	Assumption
Age at initiation			35			n.a.	McCoy et al, 2017 (Tanzania) (28) Haas et al, 2015 (multi-country SSA)
CD4 count at initiation			200			n.a.	McCoy et al, 2017 (Tanzania) (28)
Transition probabilities per cycle							
Remaining in care and virally suppressed (ICS)							
at 6 months			0.685 (0.55 – 0.82)			Beta	Probability of remaining in care (Fox & Rosen, 2015 (multi-country SSA)(4)) x Rate of viral suppression (McMahon et al, 2013 (multi-country LMIC)(45))
at 12 months			0.819 (0.66 – 0.98)			Beta	
after 12 months			0.888 (0.71 – 1.00)			Beta	
Transitioning to in care but unsuppressed (ICS → ICU)							
at 6 months			0.135 (0.11 – 0.16)			Beta	Probability of remaining in care (Fox & Rosen, 2015 (multi-country SSA)(4)) – probability of remaining in care and virally suppressed
at 12 months			0.108 (0.09 – 0.13)			Beta	
after 12 months[1]			0.047 (0.037 – 0.56)			Beta	
Mortality adjusted for misclassified LTFU (IC1S → D)							
Correction factor for mortality from misclassified loss to follow-up (LTFU)			1.57 (1.2-8)			n.a.	Somi et al, 2012 (Tanzania)(14), Egger et al, 2011 (multi-country SSA)(48)
at 6 months			0.066 (0.03 – 0.10)			Beta	Assumed 3-month mortality from Brennan et al, 2016 (multi-country)
at 12 months			0.024 (0.01 – 0.035)			Beta	Fox & Rosen, 2010 (multi-country SSA)
after 12 months - other cause mortality:						Beta	
35-39 years	0.003 (0.003-0.004)	0.004 (0.003-0.005)	0.002 (0.002-0.003)	0.009 (0.007-0.011)	0.005 (0.004-0.006)		WHO life tables Per cycle transition probability was calculated as: 1 - (1 – five year probability)$^{1/10}$ (41)
40-44 years	0.004 (0.003-0.005)	0.005 (0.004-0.006)	0.003 (0.002-0.003)	0.011 (0.009-0.013)	0.005 (0.004-0.006)	Beta	
45-49 years	0.005 (0.004-0.006)	0.005 (0.004-0.007)	0.003 (0.003-0.004)	0.012 (0.009-0.014)	0.006 (0.005-0.007)	Beta	
50-54 years	0.006 (0.005-0.007)	0.006 (0.005-0.008)	0.005 (0.004-0.006)	0.012 (0.009-0.014)	0.008 (0.006-0.009)	Beta	
55-59 years	0.007	0.007	0.006	0.012	0.010	Beta	

Parameter	Tanzania	Zambia	Ethiopia	Lesotho	South Africa	Distribution	Source(s)
	(0.006-0.008)	(0.006-0.009)	(0.005-0.007)	(0.010-0.014)	(0.008-0.012)		
60-64 years	0.010 (0.008-0.012)	0.010 (0.008-0.012)	0.009 (0.008-0.011)	0.015 (0.012-0.018)	0.015 (0.012-0.017)	Beta	
65-69 years	0.015 (0.012-0.018)	0.015 (0.012-0.018)	0.015 (0.012-0.018)	0.020 (0.016-0.024)	0.021 (0.017-0.025)	Beta	
70-74 years	0.023 (0.018-0.028)	0.024 (0.019-0.028)	0.024 (0.019-0.028)	0.030 (0.024-0.036)	0.030 (0.024-0.036)	Beta	
75-79 years	0.035 (0.028-0.042)	0.038 (0.030-0.046)	0.038 (0.031-0.046)	0.047 (0.037-0.056)	0.042 (0.034-0.051)	Beta	
80-84 years	0.051 (0.041-0.061)	0.061 (0.049-0.074)	0.062 (0.049-0.074)	0.073 (0.058-0.087)	0.062 (0.050-0.075)	Beta	
85-89 years	0.072 (0.057-0.086)	0.095 (0.076-0.114)	0.096 (0.077-0.115)	0.109 (0.087-0.131)	0.088 (0.071-0.106)	Beta	
90-94 years	0.094 (0.076-0.113)	0.140 (0.112-0.168)	0.141 (0.113-0.170)	0.158 (0.126-0.189)	0.124 (0.099-0.149)	Beta	
95-99+ years	0.116 (0.093-0.14)	0.192 (0.154-0.231)	0.194 (0.155-0.233)	0.211 (0.169-0.253)	0.167 (0.134-0.201)	Beta	
Disengaging from care (ICS→OOC1)							
at 6 months			0.114			Beta	Residual probability
at 12 months			0.050			Beta	
after 12 months (cycles 3-10)			0.062			Beta	
Transition probabilities from In Care Unsuppressed State							
Remaining in state (ICU)			0.363			Beta	Residual probability
Achieving viral suppression in first-line care (ICU→ IC1S)			0.50 (0.1-0.6)			Beta	Assumption. Reduced by 0.1 for every subsequent five-year period, and capped at 0 from cycle 101.
Switching to second-line therapy from ICU (ICU→IC2S)			0.045 (0.01-0.10)			Beta	Assumption using annual switching probability from Kityo et al, 2014 (Uganda)(82)
Disengaging from care (ICU→OOC1)			0.05 (0-0.5)			Beta	Assumption. Increased by 0.1 for every subsequent five-year period until cycle 80, then reduced to adjust for increased mortality.
Mortality after 6 months (ICU→D)[2]			0.042 (0.01-0.08)			Beta	Fox & Rosen, 2010 (multi-country) (83)

Parameter	Tanzania	Zambia	Ethiopia	Lesotho	South Africa	Distribution	Source(s)
							Increased for every 5-year period at the same rate as all cause mortality
Transition probabilities from Out of Care 1 State							
Returning to care from being out of care (OOC1→IC1U)			0.230 (0.03-0.43)			Beta	Kranzer & Ford, 2011 (84)
Remaining out of care for a second cycle (OOC1→OOC2)			0.526			Beta	Residual probability
Mortality if out of care for 1 cycle (OOC1→D)			0.244 (0.10-0.50)			Beta	Van Cutsem et al, 2011 (47) Increased for every 5-year period at the same rate as all cause mortality, but capped at 0.77.
Transition probabilities from Out of Care 2 State							
Mortality if out of care for at least 2 cycles (OOC2→D)			0.349 (0.10-0.99)			Beta	Van Cutsem et al, 2011 (47) Increased for every 5-year period at the same rate as all cause mortality, but capped at 1.
Remaining out of care for more than 2 cycles (→OOC2)			0.651 (0.01-0.9)			Beta	Residual probability
Costs (USD 2015) per cycle							
Cost in ART care (IC1S), first-line	147 (66-640)	312 (115-881)	100 (40-356)	259 (98-874)	365 (173-1,068)	Gamma	Median (min-max) from Menzies et al, 2011 (Ethiopia, Nigeria, Uganda, Botswana)(65); Marseille et al, 2012 (Zambia)(63); Tagar et al, 2014 (South Africa, Zambia, Ethiopia, Rwanda, Malawi)(64) adjusted for each country
Cost in ART care (IC2S), second-line	559 (279-838)	587 (294-1,107)	541 (271-812)	568 (284-851)	712 (356-6,632)	Gamma	Rosen et al, 2011 (South Africa) (67)
Cost in ART care unsuppressed (IC1U), first-line	148 (68-657)	314 (118-906)	100 (41-364)	260 (101-898)	367 (180-1,107)	Gamma	Rosen et al, 2008 adjustment (South Africa) (66)
Health care cost of being out of ART care (OOC1 and OOC2)	123 (47-246)	112 (81-224)	48 (25 - 97)	137 (67-275)	761 (269-1,522)	Gamma	Guinness et al, 2002 (Kenya) (68), Rosen et al, 2008 (South Africa) (66)
End-of-life costs (D)	37 (19-56)	45 (23-68)	32 (16-48)	40 (20-60)	97 (49-146)	Gamma	Goldie et al, 2006 (Cote d'Ivoire) (69)
Provider cost of 6-month food assistance	198 (885)	249 (1,410)	167 (538)	215 (1,152)	592 (6,448)	Gamma	Afya costing study (see appendix 3 S5); upper bound from Posse et al, 2013 (Mozambique) (71)

Parameter	Tanzania	Zambia	Ethiopia	Lesotho	South Africa	Distribution	Source(s)
Disutilities and discount rates per cycle							
Disability weight for HIV/AIDS on treatment			0.026 (0.01-0.04)			Gamma	Salomon et al, 2012 (73)
Disability weight for symptomatic, pre-AIDS			0.111 (0.06-0.17)			Gamma	
Disability weight for AIDS, not on treatment			0.274 (0.14-0.41)			Gamma	
Disability weight for death			0.25 (0.13-0.38)			Gamma	Half-cycle adjustment (41)
Discount rate for costs			0.03 (0.0-0.05)			Log normal	iDSI reference case (72)
Discount rate for outcomes			0.03 (0.0-0.05)			Log normal	iDSI reference case (72)
Intervention effects							
Adjusted risk ratio for adherence measure (MPR>95%)			1.25 (1.09-1.5)			Log normal	McCoy et al, 2017 (Tanzania) (28) Tirivayi et al, 2012 (Zambia) (24)
Association between optimal adherence and virologic failure			0.34 (0.26-0.44)			Log normal	Bezabhe et al, 2016 (multi-country) (55)
Intervention risk ratio for probability of being in care and suppressed (in first cycle)			1.18 (1.07-1.28)			Log normal	Effect on adherence x (1 – association between optimal adherence and virologic failure)
Risk ratio in subsequent cycles for maintained adherence effect			1.00 (1.036)			Log normal	None (to 20%) of the adherence effect maintained
Adjusted risk ratio for probability of dying or being LTFU (in first cycle)			0.138 (0.90)			Log normal	McCoy et al, 2017 (Tanzania) (28) Lamb et al, 2012 (multi-country) (23)
Transmission model parameters							
HIV prevalence	0.047 (0.042-0.053)	0.129 (0.123-0.134)	0.02 (0.018-0.022)	0.227 (0.208-0.243)	0.192 (0.184-0.20)	Beta	UNAIDS (2)
Base probability of HIV transmission per act			0.0033 (0.0006-0.006)			Beta	Boily et al, 2009 (85)
Multiplier for the effect of condom use	0.79 (0.71-0.87)	0.86 (0.77-0.95)	0.94 (0.89-0.98)	0.77 (0.69-0.85)	0.67 (0.60-0.73)	Beta	Calculated as condom efficacy x average condom use. Condom efficacy = 0.8 (86, 87). See text S2
Multiplier for the effect of male circumcision	0.50 (0.45-0.55)	0.78 (0.70-0.86)	0.54 (0.49-0.60)	0.59 (0.53-0.64)	0.66 (0.60-0.73)	Beta	Male circumcision efficacy = 0.6 (88)
Number of acts per partner per year	38 (19-57)	69 (55-83)	36 (29-43)	61 (49-73)	63 (51-76)	Gamma	Spectrum/Goals (57)
Number of partners per year	8 (4-12)	3 (2-5)	4 (2-6)	3 (2-5)	11 (5-16)	Gamma	Spectrum/Goals (57)
Multiplier for the effect of stage of infection			4.45 (1-8)			Beta	Spectrum/Goals (57)

Parameter	Tanzania	Zambia	Ethiopia	Lesotho	South Africa	Distribution	Source(s)
Multiplier for effect of treatment			0.04 (0.01-0.10)			Beta	Hazard ratio for HIV incidence among serodiscordant couples on ART Cohen et al, 2011 (56)
Discounted lifetime ART costs	7,224 (5,618-8,427)	7,667 (6,134-9,200)	6,948 (5,558-8,338)	7,343 (5,874-8,812)	12,430 (9,944-14,916)	Gamma	Cleary et al 2008 (89)
Intervention food security effects and opportunity costs							
Risk ratio for severe food insecurity			0.76 (0.6-0.97)			Log normal	Palar et al, 2015 (Honduras) (59)
Base case food insecurity (6 months after the intervention)			0.67 (0.50-0.80)			Beta	Fahey et al, 2017 (Tanzania)
Unit cost of alternative food security intervention (cash transfer)	118 (56-176)	219 (109-328)	64 (32-96)	148 (74-222)	778 (389-1,167)	Gamma	Chiwele 2010 (Zambia) (79)
Percentage point increase in not severely food insecure households among cash transfer beneficiaries			0.177 (0.09-0.27)			Log normal	Seidenfeld et al 2014 (Zambia) (80)
Cost per household food insecurity averted	332	618	180	418	2,197	Gamma	Calculated from above parameters

Notes: Parameters used in the main analysis are followed by the lower and upper bounds used in the probabilistic sensitivity analysis between parentheses. [1]After 100 cycles, this is conservatively used as the clearing variable, as mortality increases. [2]After cycle 10, this is increased at the same rate as 'all-cause mortality' from the WHO life tables.

7.3 Results

In the base case cohort simulation (no food assistance), nearly 60%, 35% and 23% of the food-insecure patients initiating ART would be alive after 5, 10 and 15 years in all 5 countries, respectively, with marginally lower figures in Lesotho (see appendix 3 Figure S5). The lifetime of the cohort – i.e. the time between ART initiation and the death of the last person – ranged from 60 years in Lesotho, to about 67 years in Tanzania, Zambia, Ethiopia, and South Africa. Between 19,342 (Lesotho) and 24,985 (Ethiopia) DALYs would have been lost in this cohort of 1,000 patients, mainly due to premature death (see Table 7.2). 12% of deaths would have occurred in the first 6 months after initiation.

At 5 years post-initiation of ART an estimated 51% of the cohort would still be in care, and of those 91% would be virally suppressed (see appendix 3 Table S4). Just over 6% of those in care would have switched to second-line therapy. Around 8-9% of those who were alive would have disengaged from care. After about 25 years, all those who were still alive would be in care.

The introduction of the 6-month food assistance intervention would lead to an increase in survival to 69%, 40% and 27% at 5, 10 and 15 years after initiation, respectively (again slightly lower figures in Lesotho) (see appendix 3 Figure S6). As presented in Table 7.2, this would result in a concomitant reduction in DALYs over the lifetime of the cohort to between 18,229 (Lesotho) and 23,426 (Ethiopia). With incremental costs between USD327,138 (Ethiopia) and USD1.2 million (South Africa), the intervention would have a mean cost of USD210 per DALY averted in Ethiopia; USD310 per DALY averted in Tanzania; USD556 per DALY averted in Zambia; USD600 per DALY averted in Lesotho; and USD889 in South Africa. These estimates are all below half the countries' GDP per capita and therefore cost-effective, except in Lesotho where it is just over the threshold. In all cases, there would be a net benefit of the intervention, with the highest economic return in Ethiopia and the lowest in South Africa.

Taking a broader perspective to consider potential intervention effects on secondary HIV transmission, we found that given the improvement in survival, there was only a reduction in HIV transmission in the first year or two, followed by increased transmission from the fact that more people were alive. This led to a slight increase in future ART costs across the board, and minor changes in DALYs averted, which did not change the cost-effectiveness significantly, except in South Africa where it became more cost-effective (see Table 7.2).

Finally, in the multi-sectoral perspective with co-financing, we estimated that the intervention would pull 160 individuals in the cohort and their households out of severe food insecurity in the first 6 months on ART (with no sustained effect thereafter). Given what is spent on cash transfer programmes to achieve this same food security outcome, we estimated that the social protection payer would be willing to contribute between USD29,000 (Ethiopia) and USD352,000 (South Africa) to the intervention costs (see Table 7.2). This represents 17% to 60% of the

direct intervention costs, but only 9% to 27% of the total incremental costs from its implementation over the cohort's lifetime (including indirect costs from increased health service use and net ART costs/savings from secondary infections). The cost per DALY averted for the HIV payer is thus reduced to USD191 in Ethiopia; USD278 in Tanzania; USD501 in Zambia; USD536 in Lesotho; and USD566 in South Africa. It therefore becomes more cost-effective and provides an economic return of up to USD3.9 for every dollar invested in Ethiopia.

As illustrated in the panel in Figure 7.2, if policy-makers would fully discount future costs and benefits beyond 5 or 15 years, and thereby take a more short-term approach to prioritisation, the intervention would be cost-effective across all countries and even cost-saving in the broader perspectives in South Africa and Tanzania.

Univariate sensitivity analyses are presented in Figure 7.3 for the multi-sectoral perspective. We find that the intervention's cost-effectiveness is very sensitive to the cost of the intervention and the size of the adherence and attrition effects. In particular, if the intervention cost was closer to the estimate in Posse et al (71) (which was a larger food basket), it would not be cost-effective in any of the 5 countries (see Figure 7.3e). Even a moderate maintenance of 20% of the adherence effect over the cohort's lifetime would make the intervention cost-saving in all countries. Surprisingly, a reduced attrition effect would improve cost-effectiveness, possibly because of less HIV transmission and related ART costs from patients who would die earlier. The result for South Africa is the most sensitive to variations in model parameters, but due to its much higher threshold (higher GDP per capita), it remains cost-effective in most cases. Our results are moderately sensitive to the DALY discount rate, but less sensitive to the food security effect, mortality correction factor to adjust for misclassified LTFU and the switching rate to second-line therapy.

Results from the probabilistic sensitivity analysis and the cost-effectiveness acceptability curves (see Figure 7.4) suggest that the intervention is likely to be cost-effective for all perspectives in Tanzania, Zambia, and Ethiopia. It may even be cost-saving in South Africa. For a WTP threshold of half each country's GDP per capita, the probability that the intervention would be cost-effective is highest in South Africa (90-92%), followed by Ethiopia (81-84%), Tanzania (74-79%), and Zambia (65-71%). For Lesotho, it is least likely to be cost-effective (42-53%).

When we run the model with the expected cohorts of eligible patients receiving the intervention from 2016-2020, we find a similar pattern across countries. The incremental costs until 2030 of implementing the intervention would be USD92 million in Tanzania, or USD75 million with co-financing, and it would avert about 9,500 deaths and 555,700 DALYs, as well as resulting in nearly 48,000 fewer households being food-insecure for the first 6 months following ART initiation. In Zambia, the incremental cost would be between USD74 million and USD89 million, for about 5,200 deaths and 279,500 DALYs averted, as well as 25,000 fewer food-insecure households. In Ethiopia, for an incremental cost between USD24 million and USD27 million,

about 3,000 deaths, 192,300 DALYs and nearly 16,000 cases of household food insecurity would be averted. The findings for Lesotho suggest that the intervention would cost between USD20 million and USD24 million, and avert 72,700 DALYs, 1,600 deaths, and 7,800 food-insecure households. Finally, South Africa, with its low levels of food insecurity but large number of patients initiating ART, could provide 6-month food assistance to severely food-insecure patients for the next five years and save between USD35–55 million, and avert 1,900 deaths, 400 new HIV infections and 124,400 DALYs, as well as prevent about 9,200 cases of household food insecurity.

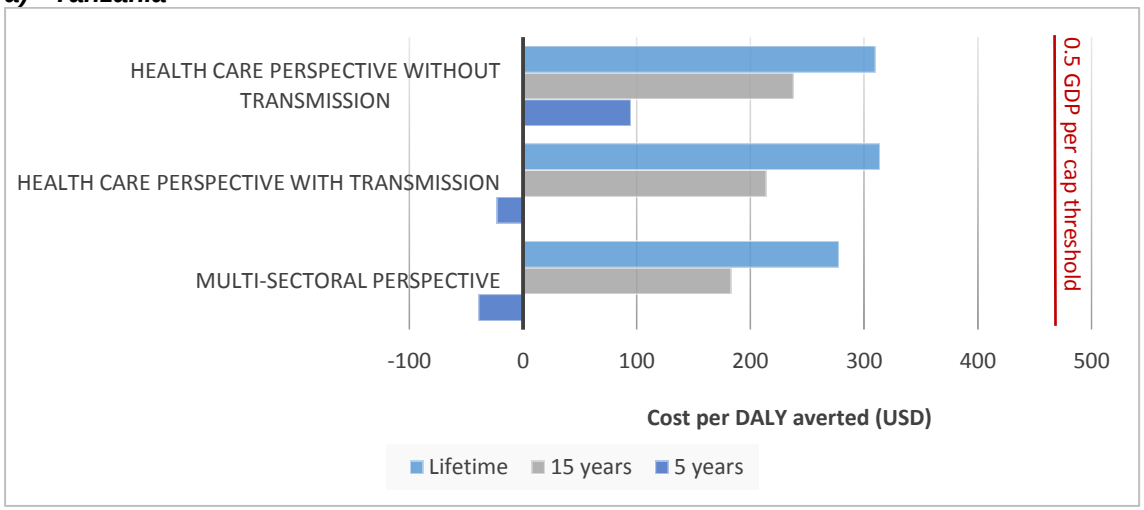
Table 7.2 Cost-effectiveness and economic returns over cohort lifetime

	Tanzania	Zambia	Ethiopia	Lesotho	South Africa
Base Case					
Costs (USD)	2,968,683	4,760,264	2,314,350	3,967,025	6,520,376
DALYs	23,016	23,661	24,985	19,342	22,242
Intervention case 1: Health care cohort perspective without transmission					
Costs (USD)	3,415,422	5,564,502	2,641,489	4,634,819	7,737,829
DALYs	21,573	22,214	23,426	18,229	20,873
Incremental costs (USD)	446,739	804,238	327,138	667,794	1,217,453
Incremental DALYs averted	1,443	1,447	1,559	1,113	1,369
ICER (USD)	310	556	210	600	889
BCR	3.2	1.8	4.8	1.7	1.1
Intervention case 2: Health care perspective with transmission					
Incremental costs (USD)	463,578	840,045	327,883	677,628	1,305,615
Incremental HIV infections averted	-24	-29	-2	-22	-207
Incremental DALYs averted	1,476	1,480	1,562	1,140	1,685
ICER (USD)	314	568	210	595	775
BCR	3.2	1.8	4.8	1.7	1.3
Intervention case 3: Multi-sectoral perspective					
Incremental costs (USD)	410,371	741,032	299,018	610,572	484,401
Incremental DALYs averted	1,476	1,480	1,562	1,140	1,685
ICER (USD)	278	501	191	536	566
BCR	3.3	1.9	4.9	1.8	1.6

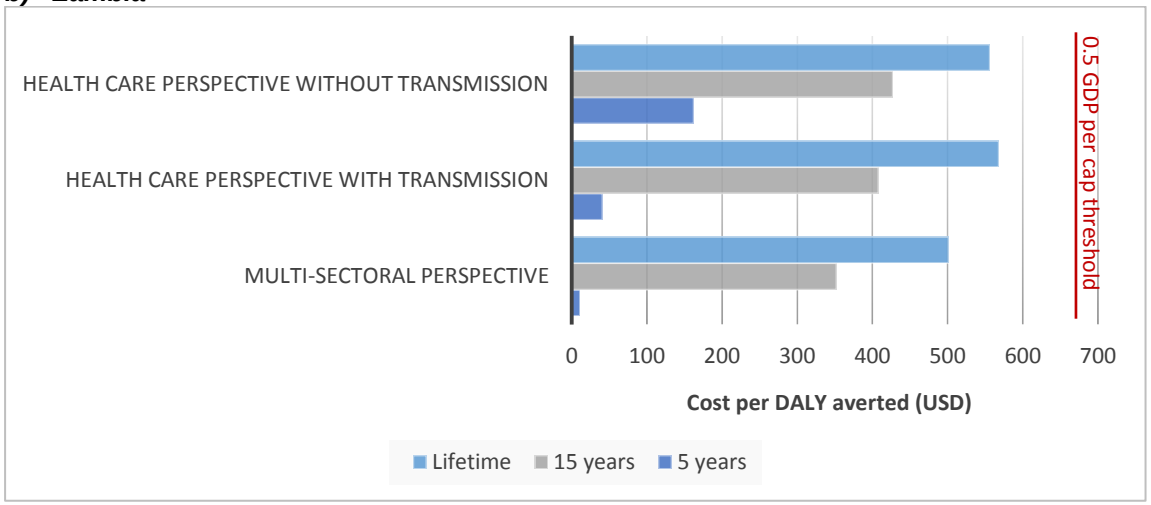
Note: DALY: Disability-Adjusted Life Years, ICER: Incremental Cost-Effectiveness Ratio; BCR: Benefit-Cost Ratio. All costs and benefits are discounted at 3%. Incremental costs and outcomes under each perspective are incremental compared to the base case. Country cost-effectiveness thresholds at 0.5 x GDP per capita are: USD 471 for Tanzania; USD 675 for Zambia; USD 344 for Ethiopia; USD 526 for Lesotho; USD 2,848 for South Africa.

Figure 7.2 Incremental cost-effectiveness at 5 years, 15 years and lifetime

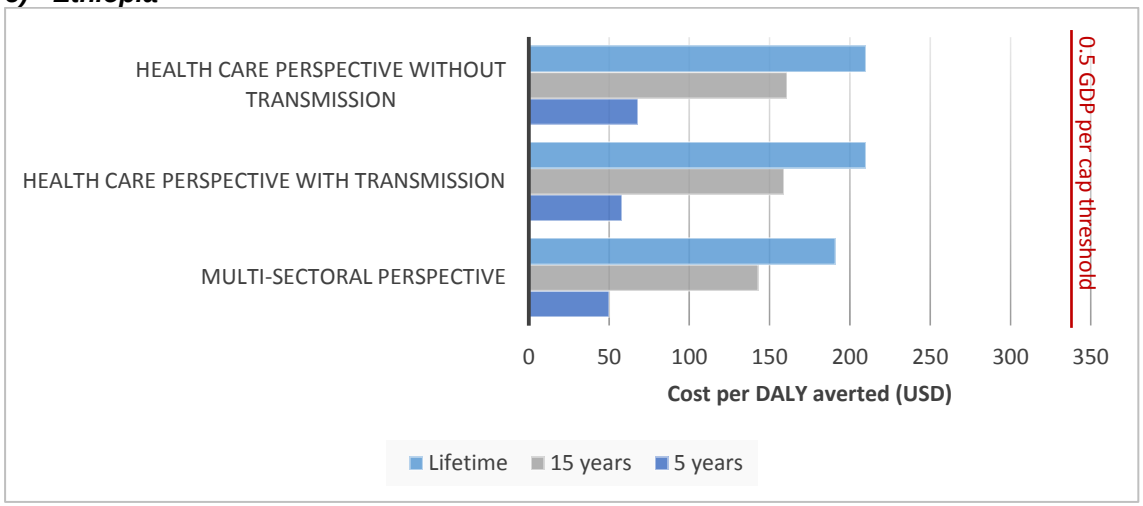
a) Tanzania



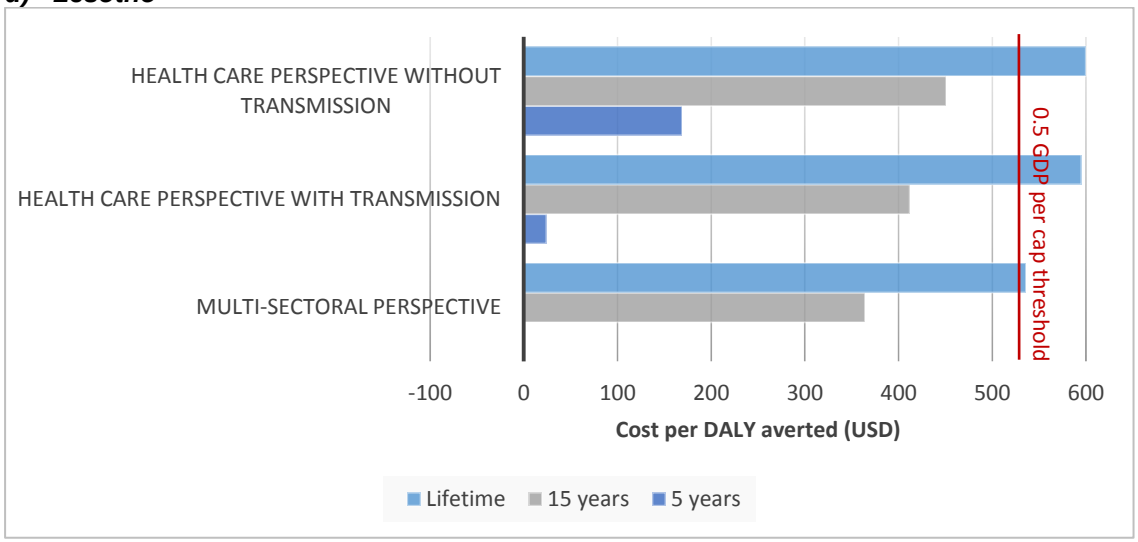
b) Zambia



c) Ethiopia



d) Lesotho



e) South Africa

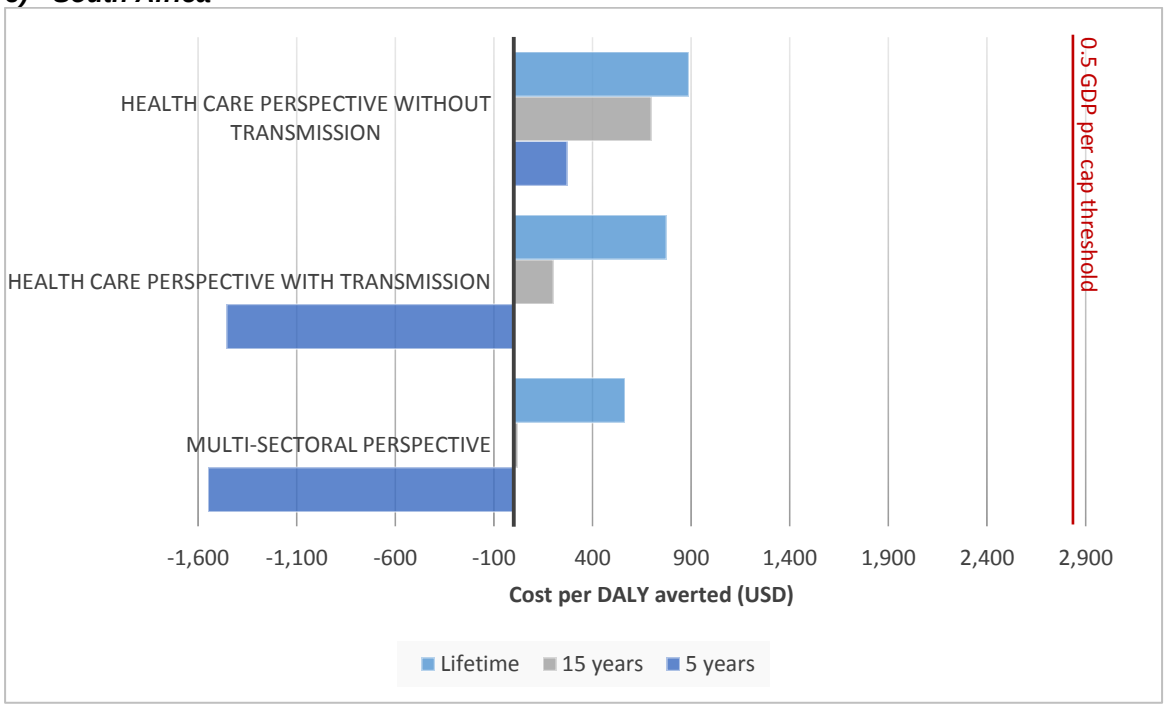
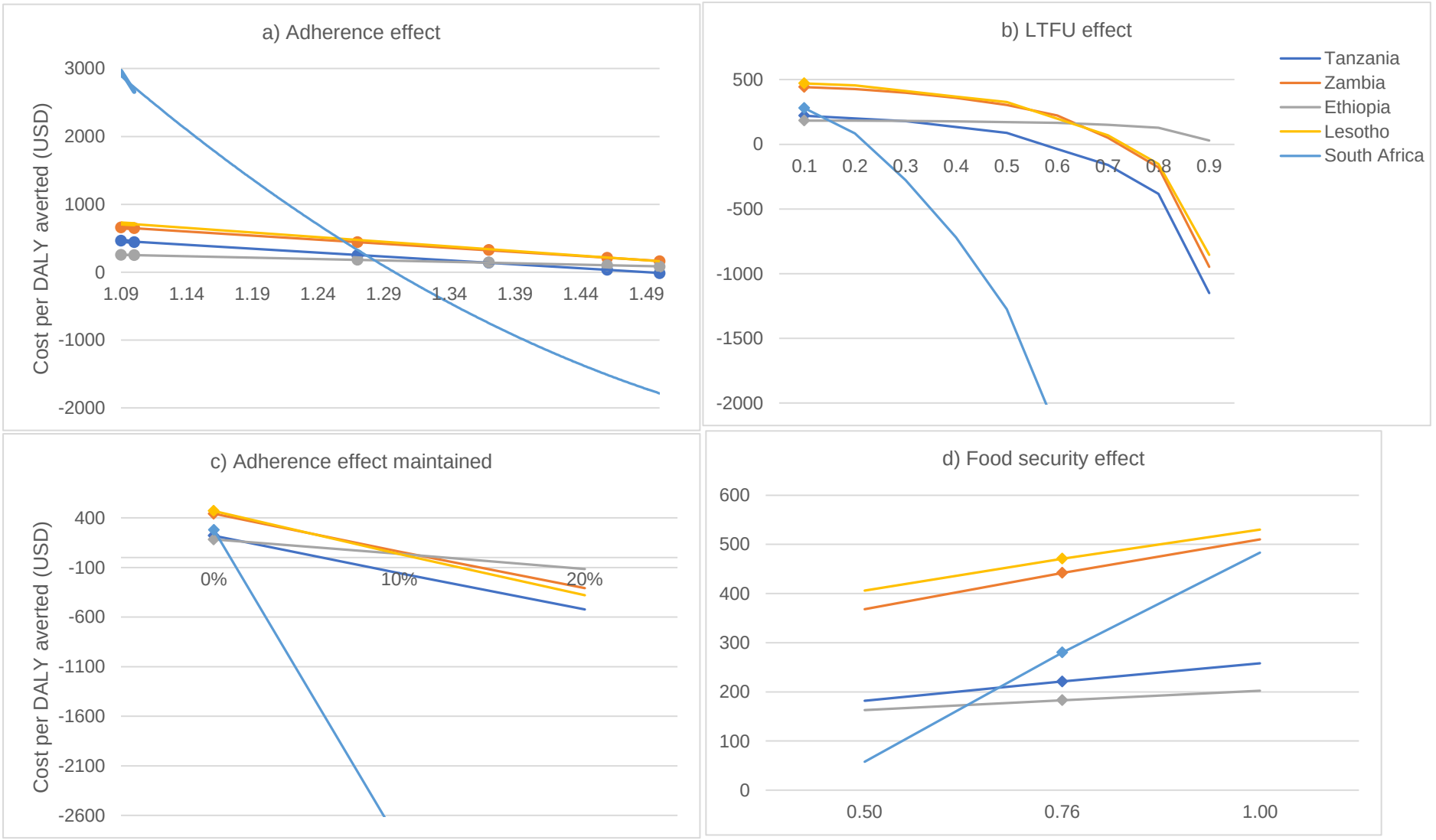
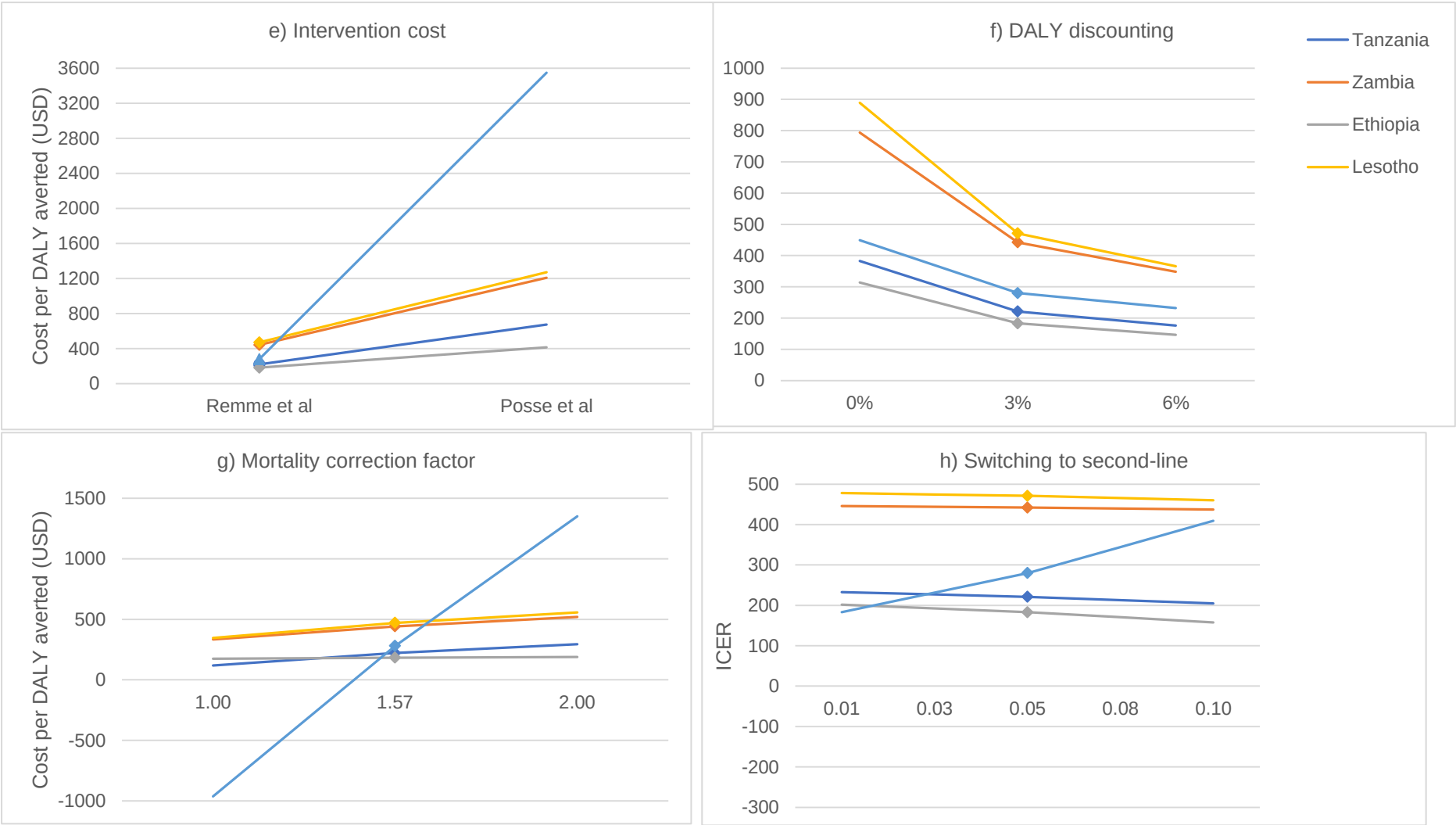


Figure 7.3 Selected Univariate Sensitivity analyses for Multi-sectoral perspective

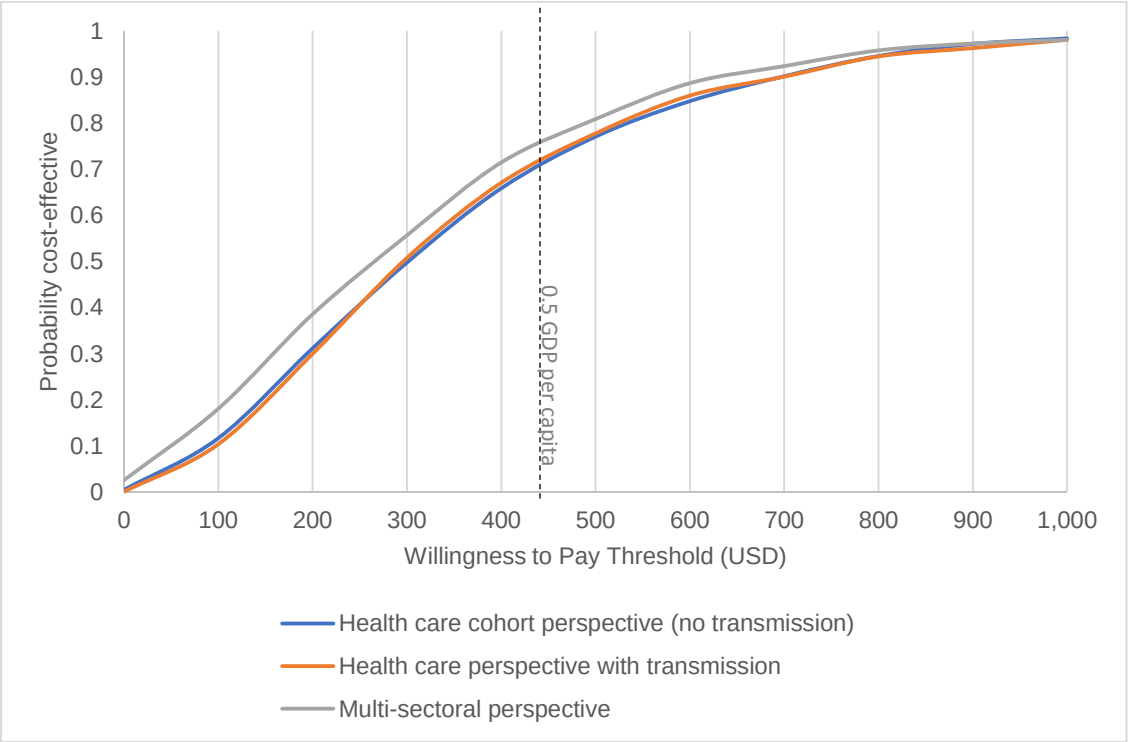




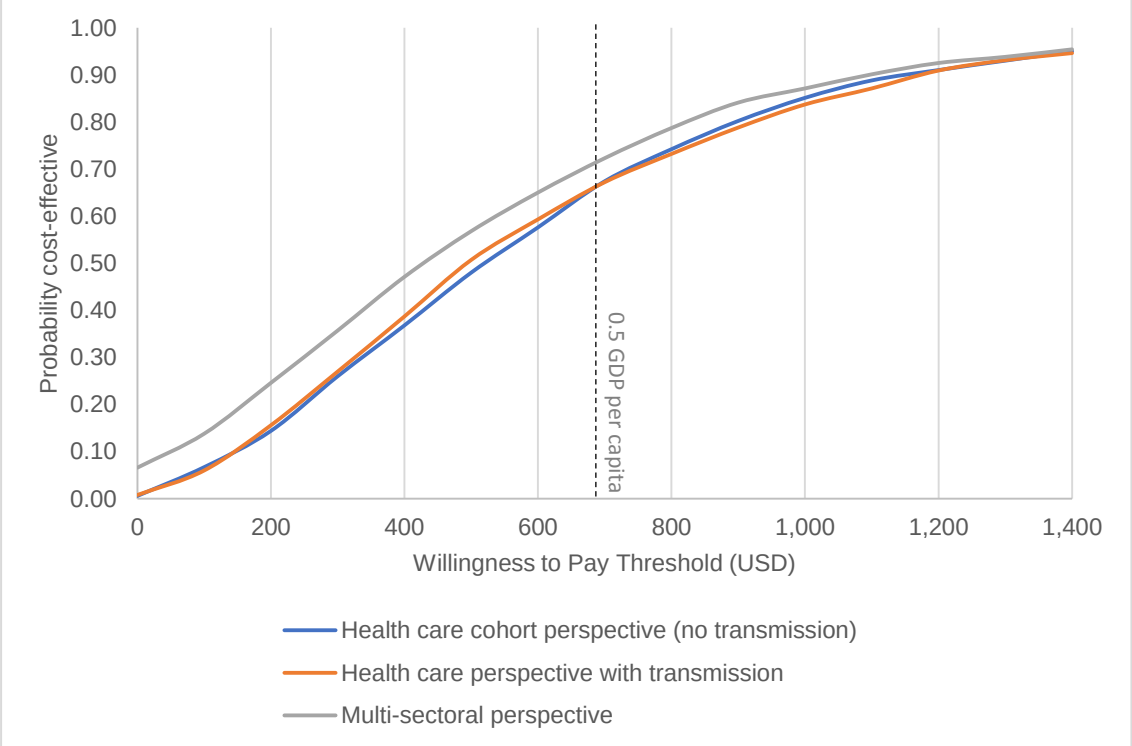
Note: The diamond labels are the point estimates in the main analysis. All negative incremental cost-effectiveness ratios are from negative incremental costs, not negative incremental DALYs, and thus represent cost savings.

Figure 7.4 Cost-effectiveness acceptability curves for each perspective per country

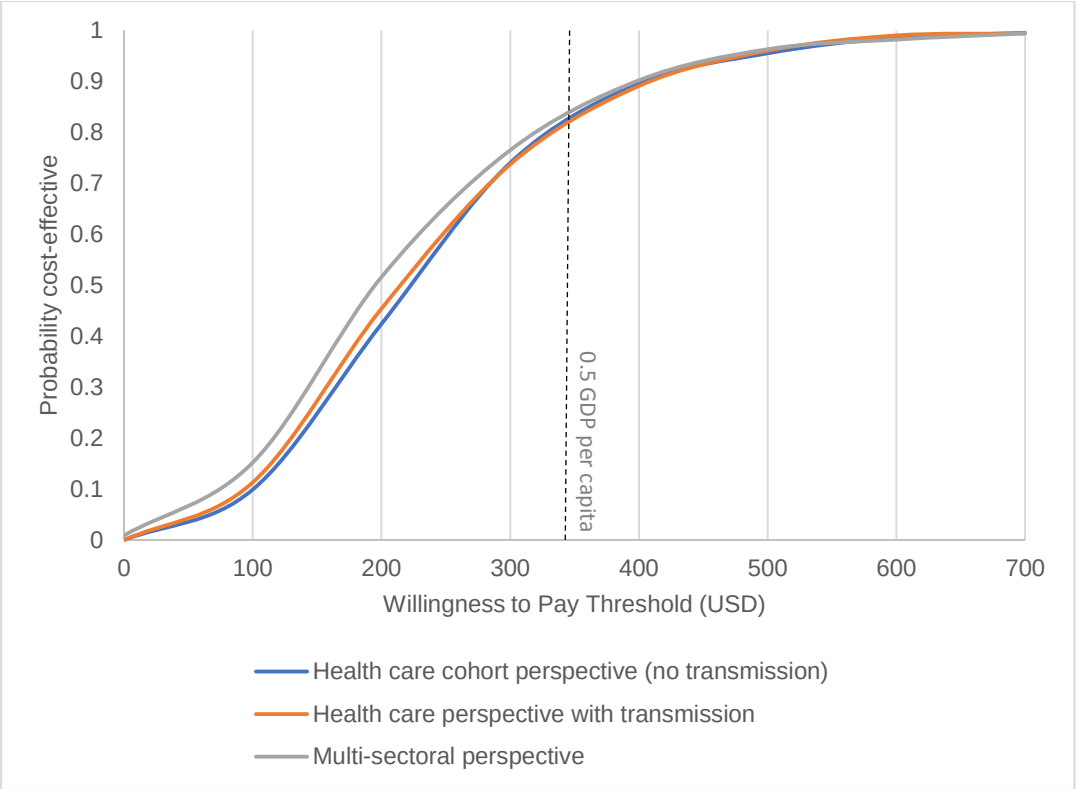
a) Tanzania



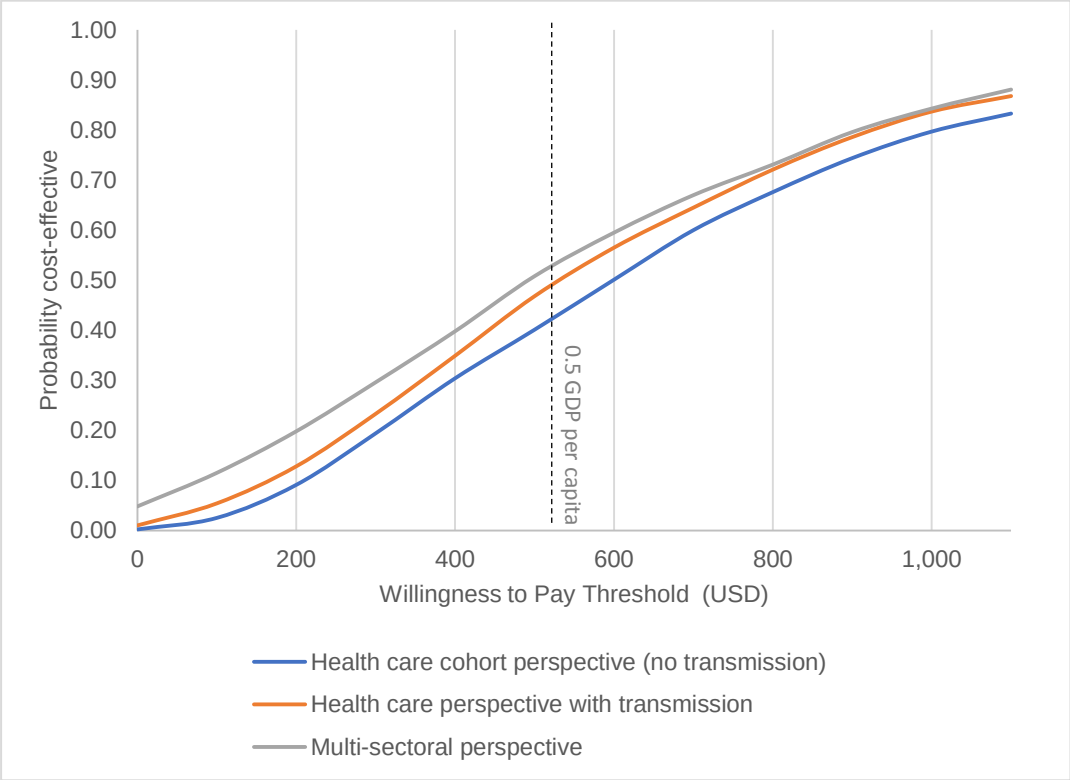
b) Zambia



c) Ethiopia



d) Lesotho



e) South Africa

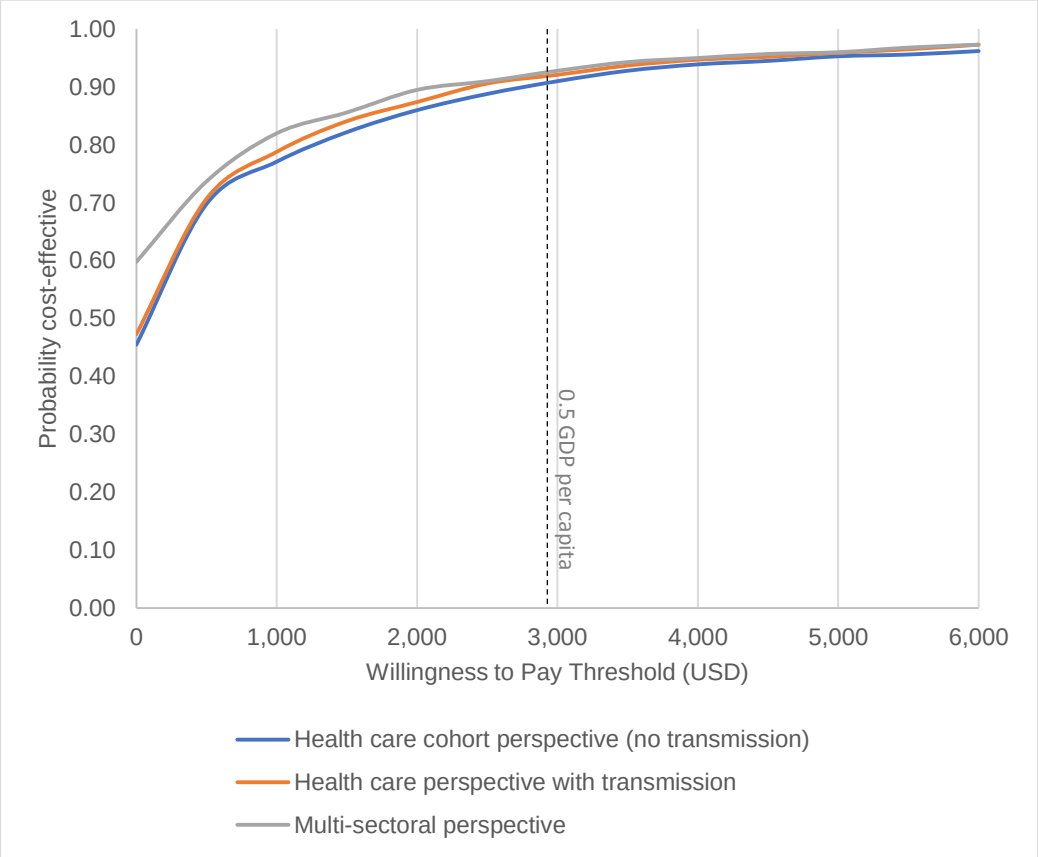


Table 7.3 Costs and DALYs averted until 2030 by implementing the intervention for 5 years (2016-2020)

	Tanzania	Zambia	Ethiopia	Lesotho	South Africa
Population					
Total ART Initiates[1] (2016-2020)	764,716	325,968	255,588	127,703	1,150,559
Proportion food-insecure[2]	39%	48%	39%	38%	5%
Total number of eligible initiates	301,298	156,465	98,913	48,527	57,528
Base Case (no intervention)					
Costs	609,721,061	533,119,195	142,852,121	146,837,318	292,726,941
Deaths	230,566	100,907	75,825	36,994	43,672
DALYs	6,252,954	3,144,866	2,232,381	831,135	1,143,546
Intervention case 1: Health care cohort perspective without transmission					
Incremental costs	117,372,680	106,438,012	27,993,715	28,455,561	63,010,642
Incremental DALYs averted	542,145	273,771	191,815	70,871	99,996
Deaths averted	9,521	5,157	3,076	1,623	1,894
ICER	216	389	146	402	630
BCR	4.6	2.6	6.9	2.5	1.6
Intervention case 2: Health care perspective with transmission					
Incremental costs	91,643,328	88,858,523	27,246,976	23,690,112	-34,907,368
Incremental DALYs averted	555,707	279,494	192,261	72,656	124,418
Infections averted	-700	-642	-14	44	423
ICER	165	318	142	326	Cost saving
BCR	6.1	3.2	7.1	3.1	n.a.
Intervention case 3: Multi-sectoral perspective					
Incremental costs	75,612,094	74,466,419	24,391,815	20,436,059	-55,168,328
Incremental DALYs averted	555,707	279,494	192,261	72,656	124,418
Food-insecure households averted (6 months)	48,292	25,077	15,854	7,779	9,221
ICER	136	266	127	281	Cost saving
BCR	7.4	3.8	7.9	3.6	n.a.

Note: DALY: Disability-Adjusted Life Years, ICER: Incremental Cost-Effectiveness Ratio; BCR: Benefit-Cost Ratio. All costs and benefits are discounted to their net present value in 2015 USD at 3% discount rate. Incremental costs and outcomes under each perspective are incremental compared to the base case. [1]Extracted from Spectrum at a 500 CD4 eligibility threshold. [2]Sources: Tanzania (90); Zambia (27); Ethiopia (91); South Africa (92); Lesotho (assumption).

7.4 Discussion

This study assessed the costs, outcomes and economic returns of a 6-month food support intervention to food-insecure patients initiating ART in different settings in sub-Saharan Africa. We hypothesised that given the evidence on the positive effects of such an intervention on retention in care and adherence to treatment, and the high rates of LTFU and mortality in the critical period immediately following ART initiation, this intervention may also be a valuable investment for particularly vulnerable groups, alongside the continued expansion of treatment. This is of significance, considering that the prevalence of moderate and severe food insecurity among people eligible for or having recently initiated ART has been found to range between 68% and 90% in parts of East Africa (90, 93, 94). We found that food assistance for this population may be a cost-effective complementary intervention for HIV treatment programmes, if its short-term effects on adherence and attrition can be generalised beyond the Tanzanian setting and if its cost is minimised. Given its potential short-term impact on household food security, it may also be valued by the social protection sector and therefore co-financed, further increasing its cost-effectiveness for the HIV payer. In Lesotho, however, it is unlikely to be cost-effective in the long-term. Looking across countries with large HIV epidemics, we found that the intervention would be expected to have a higher net economic benefit in a context like Ethiopia with low price levels, while it would only have a marginal net benefit in South Africa, where high ART costs would offset some of the monetised benefits. Taking a broader perspective to consider the potential effect on secondary HIV transmission, only slightly increased the net benefit across countries.

This study is the first economic evaluation of food assistance or nutritional support for ART patients using empirical cost and effectiveness data, as well as modelling outcomes through to DALYs, as recommended by current guidelines (72). A previous study evaluated the cost-effectiveness of a similar nutritional supplementation intervention in Zambia, using hypothetical mortality and retention effects (53), while another study estimated the cost per case of LTFU averted (based on an evaluation with significant selection bias) (95). Our study is also the first to compare costs and outcomes across different country settings.

Our findings suggest that such an intervention is likely to be cost-effective if delivered through a low-cost model with local suppliers (28). Unlike Koethe et al (2014), we find that food assistance can be good value-for-money at food unit costs well above USD 5 per quarter in Zambia (53), but would need to remain well below the overall cost per person found in a programme in Mozambique that provided a larger food basket (USD 288 per quarter) (71). Food assistance may be a good HIV investment if costs can be minimised through a smaller individual food basket, and distribution costs further contained, even in places with limited food supply. While this may be the best mode of delivery to achieve nutritional outcomes in settings with limited local food availability and poorly

functioning markets, it has substantial logistical costs. Indeed, the intervention in Mozambique understandably reported double the food costs per person, but it also had three times the non-food costs found in our study (after adjusting for income level). There has been experimentation with alternative models of delivery of assistance to food-insecure households, including vouchers and cash transfers, which can be cheaper to deliver, and may be preferred by beneficiaries where food is locally available, but their nutritional impacts have varied (28, 96-98). Future research to evaluate the cost-effectiveness of these strategies under various circumstances would be warranted.

Given the potential cross-sectoral outcomes of such a food support intervention, we adopted a co-financing approach in our modelling (60). In this conceptual investment framework, we reflected on who the potential payers were, and what they would be trying to maximise when allocating their resources between interventions. The delivery platforms used for food and nutrition support are particularly important, because they reflect financing channels and budget holders. We therefore sought to estimate what level of HIV impact and programme costs would warrant a co-financing contribution from the HIV payer if this was programmatically delivered by the social protection sector; or the ART programme. It was clear that most of the direct costs would be covered by the HIV budget in Zambia (60%), Tanzania (73%), and Ethiopia (83%). However, in South Africa, only about 40% of direct intervention costs would remain to be covered by the HIV programme, after deducting the social protection sector's share. In this case, it would probably be feasible for the HIV payer to only pay the unit costs of the food provided to HIV patients (i.e. about a third of the direct cost), as well as part of the operational mark-up, but rely on the social protection budget to cover the remaining operational costs of delivery.

The study has a number of limitations that we sought to mitigate. We made several assumptions in the design and parameterisation of our model, due to limited data availability. In the absence of survival, retention in care and viral load data from country-specific cohorts of patients that were food-insecure upon initiation, we were not able to externally validate our model. Although we used multi-country data of ART cohorts in low and middle-income countries to calibrate the model, these average outcomes are likely to be more favourable than the outcomes for patients who are food-insecure when starting ART and thus the effect of the intervention may be underestimated. The same is true when using all-cause mortality as a proxy for non-AIDS mortality rates. We adopted a similarly conservative approach across the board. For example, we did not model the increased risk of virologic failure from patients falling in and out of care (84) and the indirect effect of improved adherence on reducing the need to switch to second-line therapy – an important cost driver (89). Also, in the main analysis, we did not consider the potential long-term effect of food assistance on adherence beyond the 6-month period, although there is some evidence that improvements early on can be sustained (90, 99). The sensitivity analysis shows that this would make the intervention cost-saving in all countries. We also assumed a gender-balanced cohort and did not consider any

additional impact on vertical transmission of increasing viral suppression among pregnant women, nor any intergenerational effects of improved household food security (100). Moreover, we incorporated probabilistic sensitivity analyses to account for parameter uncertainty.

Nonetheless, further limitations remain. First, there is the underlying limitation of the memory-less Markov model, which ignores previous individual pathways between states (41). Second, although our sensitivity analysis incorporates evidence from several effectiveness studies, our primary analysis is based on a single trial in Tanzania, which may be context-specific. Third, we use a simplified static model to explore the HIV transmission effect, which would be more accurately modelled in an individual dynamic micro-simulation model. Finally, the potential incremental food security effect came from a small study from Honduras among established ART patients (not initiates) (59). Since none of the trials in sub-Saharan Africa evaluated the intervention against a food security outcome, it is unclear whether such an effect can be expected, and thus any co-financing justified. Even so, our inclusion of this as the only non-health consequence is likely to be limited (101).

Future research should consider exploring the value for money of alternative models of intervention for this food-insecure target group that have also been found to effectively improve adherence, such as cash transfers (90), economic strengthening and agricultural livelihoods interventions (32). Although not food-based, cash transfers in particular may have lower costs, broader impacts beyond HIV, and more potential for scalability in settings with food availability, functioning markets, and mobile money transfer services (97). In addition, given the major challenge in linking diagnosed patients to care, food support interventions at initiation could serve as an effective demand-side incentive to nudge people into care, thus overcoming the second major hurdle in the treatment cascade (3, 7). Combined with peer adherence support, this may be particularly effective at improving virologic outcomes (102). The economic livelihood type interventions may be better suited for 3-6 months after ART initiation, following a period of in-kind or cash support, as a means of sustaining the adherence effect and promoting a range of other socio-economic outcomes for these vulnerable households.

While food and nutrition support could play a key role in optimising HIV treatment outcomes, there is also evidence to suggest that food insecurity increases high risk sexual behaviour, especially among women and adolescent girls, and that food-based interventions targeted at this vulnerable group could impact on persistently high rates of HIV transmission (103-105). For example, school feeding and household food parcels are associated with reduced risky sexual behaviours, such as transactional and intergenerational sex (106). It would therefore be worth assessing their potential value for money, based on their envisaged effects on HIV incidence and school enrolment (107).

The new global development agenda highlights the importance of interlinkages and the indivisibility of the SDGs. Preliminary results suggest that investments in reducing food insecurity and ending hunger could contribute to better HIV outcomes, through improved treatment adherence and retention in care. HIV-sensitive social protection programmes that reach individuals at risk and affected by HIV could therefore enhance the response. Rather than competing with such complementary programmes in a zero-sum game, the HIV response might consider co-investing in them to ensure they reach optimal scale and enhance the efficiency of HIV treatment and prevention efforts.

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RESEARCH PAPER COVER SHEET

PLEASE NOTE THAT A COVER SHEET MUST BE COMPLETED FOR EACH RESEARCH PAPER INCLUDED IN A THESIS.

SECTION A – Student Details

Student	Michelle Jeanette Sayi Remme
Principal Supervisor	Prof Anna Vassall
Thesis Title	Cross-sectoral co-financing: Taking a multi-payer perspective in the financing and economic evaluation of structural HIV interventions

If the Research Paper has previously been published please complete Section B, if not please move to Section C

SECTION B – Paper already published

Where was the work published?			
When was the work published?			
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion			
Have you retained the copyright for the work?*	Choose an item.	Was the work subject to academic peer review?	Choose an item.

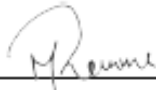
**If yes, please attach evidence of retention. If no, or if the work is being included in its published format, please attach evidence of permission from the copyright holder (publisher or other author) to include this work.*

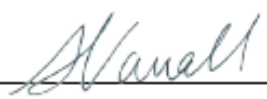
SECTION C – Prepared for publication, but not yet published

Where is the work intended to be published?	Social Science and Medicine
Please list the paper's authors in the intended authorship order:	Michelle Remme, Sophie Harman, Anna Vassall
Stage of publication	**Not yet submitted**

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	I was the lead author of this paper and conceptualised it with SH and AV. I designed and conducted the study. I drafted the full manuscript and made revisions based on comments from SH and AV.

Student Signature:  **Date:** 23/10/2017

Supervisor Signature:  **Date:** 29/10/2017

CHAPTER 8 Co-financing upstream programmes with multi-sectoral benefits: Feasibility, Barriers and Enablers in Tanzania

8.1 Introduction

The international community has adopted ambitious targets to end the HIV epidemic as a public health threat by 2030. This will require a fast-tracked response to ensure high levels of effective treatment coverage, as well as intensified prevention efforts to achieve a substantial reduction in incidence (1). However, current global estimates suggest significant challenges along the prevention and treatment cascades (2, 3), and it is increasingly recognised that these targets will not be achieved without addressing structural barriers to service uptake and adherence, as well as structural drivers of HIV risk (4). There is evidence to suggest that structural interventions, such as social cash transfers or secondary schooling, could effectively prevent HIV transmission and improve treatment outcomes, among other health and development impacts (5-9). Yet, since such interventions tend to have non-HIV primary objectives and to be implemented in other sectors, valuing them based on a single HIV outcome, is likely to lead to their under-prioritisation (10, 11), and potentially sub-optimal financing decisions (12, 13).

Pooling HIV financing with other disease-specific and broader development sector budgets to implement upstream interventions with multiple benefits - or 'co-financing' - may contribute to optimising the efficiency of HIV spending, without crowding out health system strengthening and social development programmes with spill-over HIV benefits (10, 14-17). Other sectors and disease programmes could also gain from the prioritisation of such win-win interventions, provided that costs are shared (12). For example, although an education reform to extend secondary schooling could significantly reduce HIV incidence, it may not be a cost-effective way to spend HIV resources, if assumed that the HIV budget would fund the full programme (5). Given its educational benefits, the education budget may consider funding it, but lack the resources to cover its full cost. In this case, it could be more cost-effective for both the HIV budget and the education budget to jointly contribute to the programme through a co-financing mechanism, in order to reap its full benefits (18).

In practice, such intra- and cross-sectoral coordination and joint budgeting have proven to be institutionally challenging in a number of high-income countries, in the broader context of 'joined-up government', as well as in the areas of health promotion and integrated care (16, 19-21). While there have been some successes with these mechanisms in terms of strengthening interdisciplinary and inter-organisational collaboration for mutual benefits, there have been considerable barriers, related to professional identities, differential power relationships, lack of

trust, legislative obstacles, entrenched sectoral accountabilities and unresolved value pluralism (20-23).

Yet, the changing development and HIV financing landscape may heighten the need to make integrated approaches work (24). The new global development agenda and its 17 interconnected Sustainable Development Goals (SDGs) calls for effective inter-sectoral coordination and action (25). While the HIV sub-sector's appetite for financing structural interventions was previously low (11), the constriction of international HIV financing may create the policy space for more innovative financing approaches that leverage other sectoral investments (24, 26).

This study seeks to understand the operational feasibility, as well as the institutional barriers, enablers, and (dis)incentives to adopting a co-financing framework for programmes with multiple benefits, with a focus on structural HIV interventions in Tanzania. As a low-income country with a generalised HIV epidemic, an HIV response that is almost entirely externally-financed and multiple competing development priorities, Tanzania could stand to benefit from financing mechanisms that yield efficiency gains and cost savings across sectors (27).

In this paper, we first present the study setting and methods used to explore policy-makers' perceptions about resource allocation and how co-financing might fit into existing processes. Next, we report on our findings from the qualitative analysis of interviews with these decision-makers, focusing on institutional structures, barriers and enablers. Finally, we discuss the implications of our findings for the application and adoption of co-financing for upstream programmes.

8.2 Methods

To understand the real-world feasibility of adopting a co-financing approach to resource allocation, the study sought to elicit insights from decision-makers directly involved in planning and budgeting in Tanzania. The theoretical underpinnings of the study are rooted in the positivist discipline of health economics, with insights from political economy theories (28). Although there is likely an objective reality of how resources are allocated, it is acknowledged that the interaction between the researcher and the research subjects would allow for a joint construction, or co-production and interpretation of the institutional feasibility of applying this relatively novel approach to public financing (29).

The study built on previous work to develop and specify the co-financing framework, and two case studies of cash transfer interventions with empirical evidence of multi-sectoral HIV and non-HIV impacts in Tanzania and Malawi (7, 9). To ground the interviews in the national context and reality, and minimise hypothetical biases, the study drew on the Tanzanian national cash transfer programme (TASAF) as a tangible example to explore for co-financing (30). Below, we

describe the co-financing framework, followed by the study setting and cash transfer intervention focus, before explaining our data collection and analysis methods in more detail.

Co-financing conceptual framework

It is well accepted that population health is a result of several biological, environmental, behavioural and social factors, and while access to quality health care services is critical, there are a range of other non-health interventions that contribute to improvements in health outcomes (31). Yet, the theory and to a large extent the reality of priority-setting for health, tends to focus on intervention options within the health care system (32-36). Moreover, when considering economic efficiency in resource allocation, the dominant evaluation framework of cost-effectiveness analysis is built around comparing the relationship between health care inputs (*costs*) and a single measure of health gain (*either in natural units, disability-adjusted or quality-adjusted life years*). Non-health interventions with non-health primary objectives are therefore likely to be undervalued, given that their other benefits will not be factored in (37). While this may explain why such interventions are rarely considered by health decision-makers, it could also lead to inefficient resource allocation and ultimately health losses (12). The recommended approach for the economic evaluation of such interventions is to conduct a cost-benefit analysis, where all the benefits of interventions are monetised, thereby allowing for multi-sectoral outcomes to be valued. However, the public health and medical community tend to exclude this approach, given the controversial requirement of converting health outcomes and thus lives into monetary values (38).

The co-financing approach, on the other hand, is embedded in the current cost-effectiveness framework, while enabling non-health benefits and payers to be part of the equation (10). It would allow a health payer to re-allocate part of its budget to non-health interventions that achieved a health gain more efficiently than its least efficient health care intervention (its opportunity cost), provided that other benefiting sectors would also contribute their own resources. Co-financing can therefore be defined as the joint financing of interventions by multiple payers with distinct disease-specific or sector-specific objectives.

There are two major assumptions underlying the approach. Firstly, each payer, or budget holder, is allocating its resources to maximise a specific outcome. Secondly, each payer has a single constraint, namely its available budget. Although it is clear that priority-setting rightfully involves several criteria and considerations (39) – of which efficiency is only one, the aim of economic evaluation is to identify the most efficient investments, and thus the trade-offs that would come from alternative allocations. From this angle, it is a reasonable simplification to assume that a rational decision-maker would be seeking to optimise their objectives, subject to the resources available. Based on the costs and multi-sectoral impacts of an intervention, the application of a co-financing approach would therefore require the identification of the key payers that are optimising the impacted outcomes, their respective budget constraints and opportunity costs.

Study setting

Tanzania's health policy is embedded in the national vision and development strategy. The National Development Vision 2025 aims to transform the nation into a middle-income and semi-industrialised country. The second National Five Year Development Plan (2016/17-2021/22) lays out the priorities and approaches the government and national stakeholders have adopted to realise this vision, with a focus on "nurturing industrialisation for economic transformation and human development" (40). The Medium Term Economic Framework (MTEF) translates this strategic plan into a realistic medium-term public expenditure programme for budgeting purposes. Based on this overarching institutional framework, each sector has further developed medium-term plans specifying their intermediate outcomes, outputs and activities. These guide the annual budgeting exercises at the national level.

The government is divided into two tiers of administration, namely the central level (including central ministries and 31 regional administrations) and the local government level (consisting of 169 districts). In the late nineties, Tanzania started implementing a local government reform programme of decentralisation by devolution (41). The reforms have devolved increasing fiscal responsibilities to the local government authorities that are now responsible for planning, budgeting, implementing and monitoring public service delivery. They plan and budget for central government resources they receive through block grants to supplement locally-generated revenues.

Official development assistance provided by bilateral and multilateral development partners remains an important source of development financing. In certain sectors, this aid represents a substantial or even the largest share of overall resources. For example, in health, 40% of total health financing was from external sources, according to the last National Health Accounts report (42). A review of public HIV expenditures reported that 98% of the response was externally-financed in 2012 (27). Development partners are therefore powerful actors in these (sub-)sectors' priority-setting and resource allocation processes (43, 44).

TASAF programme

The Tanzania Social Action Fund (TASAF) programme is a poverty reduction and social protection programme aimed at increasing income, consumption and resilience to shocks, as well as protecting the human capital of children in extremely poor households. TASAF is currently in its third phase and consists of four components: (i) the Productive Social Safety Net (PSSN), which has a cash transfer sub-component (delivered to the poorest households, partly conditional on school attendance and under-five health visits); and a public works sub-component for households with able-bodied adults; (ii) a livelihood component for those in target households that want to engage in productive income-generating activities, with skills development, community savings and livelihood enhancement grants; (iii) targeted infrastructure development; and (iv) capacity building (45).

The programme was initially funded by the World Bank through a loan, but it has since attracted additional grant funding from the UK Department for International Development (DfID), the Swedish International Development Agency (SIDA), as well as commitments from USAID. Four UN agencies are also providing technical assistance. The Tanzanian government is yet to disburse its own committed funds. PSSN was scaled up rapidly in 2014/15 and reached 70% of its target villages by mid-2016, i.e. 1.1 million households, making it the second largest cash transfer programme in sub-Saharan Africa (45).

The first component of the programme is particularly interesting in the context of co-financing, because when the pilot cash transfer scheme was evaluated, it was found to have significant impacts on increasing girls' school completion rates, reducing household members' reported morbidity, increasing household membership of community-based health insurance, and increasing households' agricultural assets (30). Given these demonstrated benefits across sectors, the example of TASAF was used to frame the study instruments.

Data collection

Data was collected in Dar es Salaam, Tanzania from December 2015 to December 2016 by the first author of this study, through a series of semi-structured interviews with national policy-makers and budget holders. Building on the potential and demonstrated multi-sectoral benefits of the PSSN, a rapid mapping was first conducted of the main relevant payers (budgetary authorities) in the HIV, health, social protection and food security sectors. Policy-makers were then purposively selected within these sectors on the basis of their positions and involvement in planning and resource allocation, and sector coordination.

The interview guide explored the principles used in resource allocation and their application to cross-sectoral programmes, as well as the perceived institutional feasibility of a co-financing approach. Specifically, it started by investigating how the planning and priority-setting within the remit of the respondent had been done for the current medium-term plan and annual budgeting cycle; what criteria were considered; what outcomes/objectives were being optimised; and what constraints each decision-maker faced.

Next, a set of questions were designed to determine each sector's opportunity cost, by eliciting decision-maker's willingness-to-pay (WTP) for key sectoral outcomes. In economics, WTP is the maximum amount an individual is willing to sacrifice to consume a good or service, and is by definition less or equal to their ability to pay (46). In health economic evaluation, the cost-effectiveness of an intervention is often compared to an estimate of society's WTP for an additional unit of health outcome (47). In a welfarist economic framework, this would represent the average across individuals' WTP, whereas in extra-welfarism, it reflects the decision-maker's marginal productivity, or how much they are currently paying to produce their most expensive unit of outcome (48, 49). To elicit the latter, questions were adapted from individual WTP methods, in particular contingent valuation that elicits a monetary value of individual's

preference for a good, service or policy change (50). This involves clearly formulating the valuation problem and describing the expected impact of the policy, and then asking the respondent to state their WTP for it. Given the limitations of these methods, the intention was not to get a precise measure of WTP, rather the expectation was that this would draw out any normative thresholds or rules of thumb that were explicitly or implicitly applied (51). As an alternative, respondents were also asked to identify their currently least efficient interventions, as an indication of their maximum WTP per unit of outcome.

Finally, the topic guide re-introduced co-financing with the TASAF example, and evidence of the programme's and other cash transfer interventions' multi-sectoral impacts. It then explored respondents' perceptions on the benefits, risks, barriers, enablers, and potential mechanisms for implementing cross-budget co-financing.

In preparation for the interviews, a document review was conducted to enable more informed discussions around national planning and priority-setting, including national development frameworks, medium-term plans and monitoring and evaluation frameworks, as well as sector-specific strategic plans and frameworks (health, HIV, social protection, agriculture). In addition, the United Nations Development Assistance Plan and other bilateral and multilateral development partners' country programme documents were reviewed.

Data analysis

The interview transcripts and the researcher's interview and post-interview notes formed the basis for the analysis, while the data from the documents reviewed were used to support and validate the issues that emerged. Principles of grounded theory were applied (52). First, we read through all the interviews to identify high-level general themes. Second, we coded each interview transcript and the interview notes using a mixed deductive and inductive approach to identify key concepts and new ideas (53). Third, we organised the data into groups of ideas or categories that were more generalizable. To evaluate the institutional feasibility of co-financing, we considered how these categories related to the assumptions of co-financing, and where they did not, we analysed to what extent co-financing could be applied within the existing resource allocation processes. The analysis was conducted in NVivo 10.

Ethical issues

Ethical approval was obtained from the LSHTM Research Ethics Committee, the University of California, Berkeley's Institutional Review Board, the Tanzanian National Institute for Medical Research (NIMR) and the Tanzanian Commission for Science and Technology (COSTECH). All study participants chose to participate and provided written consent. Interviews were anonymised and participants are quoted with reference to their broad institutional category (government, bilateral or multilateral development partner).

8.3 Results

Twenty respondents were interviewed, of which 9 were government officials, and 11 were senior officials among key bilateral and multilateral development partners. 35% were in the HIV sub-sector; 20% in the broader health sector; 25% in the social protection sector, 10% in the food security sector, and 10% in government body above the sectoral level, responsible for sector coordination or finance. 65% were departmental directors, organisational country directors, or their deputies; while 35% were senior advisors or heads of sections.

Insights from these decision-makers in the Tanzanian context revealed that the simplifying assumptions underlying the co-financing approach (and most standard health economic evaluation techniques), did not reflect the reality of resource allocation, where efficiency was only one of many considerations, and where budgetary authorities were constrained by many more factors than the level of the budget. Moreover, willingness-to-pay per outcome was not a working concept in resource allocation decisions, and would therefore not serve as a useful tool for negotiation around each benefiting payer's co-financing share. Despite these issues, the data suggested that co-financing could still be applied with some real-world adjustments, and that there were even examples of how the principles and to a certain extent the financing mechanism were already in place. Respondents identified specific enabling factors, but also several risks and barriers that would need to be overcome.

1. Co-financing appears to be institutionally feasible, as some examples exist and others are being explored

The notion of co-financing was deemed feasible by several respondents, but also met with some scepticism. The primary enabler that was consistently identified was the need for compelling evidence of impact across sectors, as the basis for any co-financing mechanism to be considered. Costs and cost-effectiveness compared to alternative investments was not often mentioned in this context. Evidence of impact seemed to be enough to bring different sectors and funders to the table.

> "I am telling you the truth it is the evidence. If it works, the modality of how we do it is not an issue." *Government official*

> "That will be possible because we have evidence on the ground that investing in this will give these results, why do you want to go alone while other people can deliver?" *Government official*

> "… anything that has evidence that shows that it is effective, we are willing to look at it, and then judge against the other methodologies that are used to see the cost benefit, and what else it is adding on…" *Bilateral development partner*

When reacting to questions about the feasibility of transferring funds from one sector ministry to another in order to achieve the former's objectives, several government officials responded positively with statements like: "Yes, it's possible."; "Why not?"; "You can, you can do that."

There were even cases where this had already happened or was seriously being considered for the TASAF programme. For example, the Tanzanian Commission for AIDS (TACAIDS) allocated its own HIV resources to TASAF during its previous phase (around 2010) to enable the inclusion of vulnerable households affected by HIV and AIDS. The Ministry of Health was considering investing in TASAF to improve its enrolment rates in the Community Health Fund. Other examples were given where line ministries transfer funds to other government departments/ministries for specific services, such as surveys from the National Bureau of Statistics.

> "because sometimes even us, we are given an assignment, you can't do it, you give money to other people who can do it for you (…) It's like contracting out… It's possible!" *Government official*

> "if I want something from TASAF, provided that it is within my mandate, they will give me money and then I will transfer to TASAF." *Government official*

Development partners were more sceptical about the institutional feasibility to co-finance within government structures:

> "in the Tanzanian context, sector ministries would have difficulties allocating money to another ministry. In fact, they don't, because they say how are we as a sector to give another sector money because it will mean deducting from our resources…" *Bilateral development partner*

Yet, there were also several examples raised by respondents where donors with different objectives had bought into the TASAF programme. This is not done on an explicit price-per-outcome basis, but it is implicitly a form of co-financing. TASAF has welcomed contributions to its pooled funding basket, and has put in place joint accountability mechanisms. It is not possible for donors to select components to fund, rather every funder is contributing to the overall programme. Nonetheless, being at the table and being involved in programme design, monitoring and evaluation, funders have been able to contribute to shaping TASAF targeting and the selection of targeted infrastructure development projects. There is some evidence to suggest that some have been able to use their contributions to catalyse programme tweaks that would enhance their specific objectives. There are several funding sources with environmental and climate change mitigation objectives, for example, which contributed to a greater focus on environmentally-responsive public works and infrastructure development projects.

> "40 percent of funds from UK comes from an environmental fund – that's how important they see it as an environmental investment" *Bilateral development partner*

> "[There was a] programme from the World Bank, of course resources were going to the Ministry of Natural Resources and Tourism and then the Ministry was channelling resources to TASAF." *Government official*

Some of the reasons why TASAF has been able to attract co-financing relate to it being perceived as a relatively low-risk programme to redirect resources to, because of its established

and well-functioning delivery system, as well as its strong financial management. This suggests that a programme may become more attractive to others to contribute to once the initial higher-risk investment is made in building a system, or a delivery platform. From a financial management perspective, the fact that heavy-weight funders are investing in a programme could signal trust and crowd in other sources of funding. TASAF was also the only government programme providing cash transfers, and was therefore possibly perceived as less threatening to other sectors or ministries' mandates.

> "The benefit is to use already organized structure. So no additional funds, they have experience, they have structures in place, logistically they are okay." *Government official*

> "We stand to gain more than losing, I mean in partnering with the World Bank or USAID – that's a good thing to do because these are the big boys in town." *Multilateral development partner*

Development partner respondents also mentioned less direct examples of co-financing, where HIV funding was used for health system strengthening interventions and for adolescent programming, based on their expected impact on HIV and other health outcomes.

> "we've recognized (…) that there was need for building of the health infrastructure within countries and so we expanded a bit there, but otherwise we are supposed to maintain a strict HIV focus with our programmes." *Bilateral development partner*

> "we have even been putting some of our limited HIV resources internally in supporting adolescent health." *Multilateral development partner*

Most respondents appeared open to transferring funds and some measures had been or could be put in place to facilitate and account for such transfers. There was some evidence of this happening (especially for TASAF), but the extent of the political will and impetus to do so remained unclear.

2. Willingness to pay is not a working concept in resource allocation, but decision-makers do have a sense of their least efficient investments or where efficiencies can be gained

Although one of the study objectives was to elicit WTP benchmarks from interviewees, it soon became clear that this concept was not being applied explicitly or implicitly in resource allocation. While none of the respondents volunteered a normative threshold that they used, when asked if they would be willing to spend USD 350 (half of Tanzania's GDP per capita) on their unit of outcome, most of them said that this would depend on the opportunity cost, or alternative use of resources, as well as on their ability to pay.

> "… the answer would be yes, emotionally, as a Tanzanian one person dying is one too many and you will get a yes from everybody in Tanzania. The question is can Tanzania afford it…" *Government official*

> "That is a very unfair question because I can't tell you what it costs to avert one infection right now. (…) so if you're asking me would you spend 350 dollars – of course I would. Would you spend 500? Of course I would. But do I have it? No. If I had it, I would spend it." *Multilateral development partner*

> "… we haven't done that analysis… we do know how much we're paying per person with HIV (…), but I don't have that data off the top of my head…" *Bilateral development partner*

> "just from onset, our per capita [health expenditure] is 50 [dollars]. I know the ability to pay, so it's very hard now to think of paying 350 [dollars] per person. And how sustainable it is." *Government official*

> "… you would also have to look at the other opportunity costs, because if you say that you take that money to that direction that means that definitely the other units have to be cancelled or they will not be there, so it's a very very difficult decision (…) there are a lot of resources coming there [for disease X]. So in terms of [disease X] if you ask us about our willingness to pay, you will find that our willingness to pay for [disease X] intervention is much higher". *Multilateral development partner*

As it soon became clear that the WTP questions would not yield meaningful results, the focus was on identifying the payer's current least efficient intervention, as a proxy for the opportunity cost. When asked about this, most respondents singled out specific interventions or programme components that they viewed as providing the least return in terms of benefits. Although none of these were based on explicit analyses of both costs and benefits, they implicitly took into account the certainty and effect size of the intervention's impact or how costly the intervention was compared to its benefits and scale. For example, in the HIV field, several respondents brought up behaviour change interventions, primarily because their impact was questioned. Several respondents also referred to management costs, as being potentially amongst the lease efficient investments, although this may be because their contribution to programmatic impacts were particularly difficult to attribute.

> "Our least efficient is behaviour change, the way it's done, because it is very labour-intensive and very difficult to show results in a short time." *Government official*

> "Management which consumes so much money is one of the most indolent, non-quantifiable parts, versus the other programme areas, but then you need them (…) They consume money but in terms of contributing to [impact], you could say well, perhaps not. So that's why we tend to minimise the expenditure on management." *Multilateral development partner*

> "… we look at budgets and (…) see that a lot of the money that we are spending is going towards planning, workshops, it's going towards training and orientation and new guidelines… They are necessary, but takes a lot of money, sometimes away from reaching the direct beneficiaries." *Multilateral development partner*

The idea of disinvesting from some of these interventions to potentially reinvest in more efficient interventions (possibly implemented in other sectors) was less appealing to some respondents.

> "I would not disinvest, rather maybe to integrate programmes and, so that we can have savings. Because I know the same targets would be reached, with less." *Government official*

> "… we've gone through prioritization process over and over and over and over again and we believe that everything we're doing is necessary (…) so there is nothing that we can say 'oh okay, great, we've been wondering what we were going to replace this with'." *Bilateral development partner*

Budget holders did not know how much they were currently spending per unit of outcome, on average or at the margin. This is therefore not a useful metric. However, most respondents had an implicit ranking of investments, and a sense of which they perceived as least efficient. This could be a starting point when exploring which funds could be transferred to another sector.

3. Strategy and target-alignment are a greater concern than efficiency

For co-financing for multiple outcomes to work, efficiency or cost-effectiveness, would have to be an important consideration in how resources are allocated between interventions. We found that efficiency is, at best, one of many considerations in priority-setting. Most interviewees referred to a standard evidence-based planning process, in which a needs assessment or situation analysis was first conducted to identify national needs and gaps to inform a medium-term plan. This formed the basis for a consultative process to select broad priority areas both in government and among development partners. Results or outcomes in each of those priority areas were set for the medium-term period – 5 years for national government or sector plans, or 2-3 years for development partners' cooperation plans.

In the government priority-setting exercises, costs and budget constraints were not explicitly mentioned as considerations. Rather, population needs (such as disease burden in health), and global targets and commitments, such as the SDGs or the 90-90-90 targets for ending the AIDS epidemic, were repeatedly referred to. Once targets were set, plans were then costed and financing gaps identified, suggesting less of a process of constrained optimisation or priority-setting and more of a normative planning process of what should be done.

While global agendas were said to influence national government planning, development partners also spoke of UN or their own organisation's or government's global strategies as the starting point for their in-country prioritisation.

> "Most of the targets and indicators are predetermined globally and we adapt them in the national context." *Multilateral development partner*

Alignment to the host government's plans and priorities was consistently brought up by development partners, who spoke of allocating their resources "to leverage government of Tanzania's resources", "complement" government efforts and "amplify results" (bilateral and multilateral development partners).

Activities were then planned within the selected priority areas to contribute directly or indirectly to the outputs or intermediate outcomes, typically based on service outputs, numbers or proportion of people reached with certain interventions. When describing this activity planning and how specific activities/interventions were prioritised and resource allocation amounts decided by budget holders, interviewees mentioned a number of considerations besides the targets to be reached or outcomes to be achieved, including their mandates and comparative advantage, feasibility of implementation (human and financial capacity), historical allocations, reasonableness, financial guidelines/directives from the Ministry of Finance or development partner headquarters, geographic focus, sustainability, etc. Costs were put forward as a constraint by a number of interviewees, but only a few discussed these in relation to their expected impact or referred to the efficiency ratio of each activity or intervention as a criterion. Those who did were all development partners.

4. Delivery instruments can be a greater constraint than different payers' budgets

The simplified notion that there are payers seeking to maximise a specific societal outcome from a defined budget allocated to that outcome, appears to be disconnected from the reality of resource allocation in Tanzania. There are several constraints, in addition to the budget constraint, that define the boundaries of budget holders' decision space. In fact, we identified a range of different budget holders or payers: (i) pure purchasers with a single objective and only a budget constraint; (ii) purchaser-service providers, who are playing the dual role of purchasing outcomes and providing services to achieve those outcomes, and are thus constrained by their service platform; and (iii) pure service providers, who are funded to provide specific services only.

Sector ministries were reported to be constrained by their so-called 'instrument', which limits the types of interventions they can allocate their resources to, namely to those delivered through their service platforms. For example, the Ministry of Health and Social Welfare is mandated to maximise health and meet impact-level health targets (infant and maternal mortality, life expectancy, disease prevalence), but it can only do so by ensuring the availability of and access to quality health and social services. These services are its 'instrument'.

> "… when you establish new Ministries, you share the instruments, the instrument is a guideline, which tells you what is the role of the Ministry in this new government (…) we have five-year development plan so every ministry tries to (…) download their strategic plan out of those national strategic ones (…) of course confined with those instruments, that instrument which you have been instructed to do." *Government official*

> "… you want to recognize that each sector has a mandate and each ministry has an instrument. You have a Ministry focusing on nutrition that is the instrument that is their mandate." *Government official*

However, there seems to be some blurriness regarding whether they are responsible for national-level outcomes that would be expected from their sector, i.e. is the Ministry of Health responsible and accountable for the overall level of health in the country, or is it responsible for

governing the health care system as one of the determinants of the population's health? Officially, it appears to be the latter, as set out in the national vision and development plan. The National Health Sector Strategic Plan IV (2015-2020) indicates that "The Government Health Policy aims to improve the health of all Tanzanians, especially those at risk, and to increase the life expectancy, by providing health services that meet the needs of the population." In practice, there appears to be some confusion. Several interviewees invoke the 'instrument' as a constraint and reason why one ministry could not transfer its funds to another ministry, even if it were for the achievement of its objectives. Yet, others refer to the high-level outcome as the ministry's responsibility and primary objective.

> "the President just issued the instrument, the Ministry of Agriculture will be responsible for promoting the agriculture crops, will be responsible for ensuring food security, will be responsible for preserving food from eventualities and so on…" *Government official*

> "When the president is actually elected into office, he forms the government, so he gives each ministry an instrument to show their mandate (…) So we work on that mandate (…) Even if you impact somebody else, but it's not going to be in your objectives (…) [Other sector ministries] have other objectives. You know, we go with instrument. They don't have that instrument. The only Ministry which has the health instrument is [the Ministry of Health]. So [other ministries] do things which they impact health, but they don't have that instrument." *Government official*

> "… it was outlined in the MKUKUTA that, overall, in terms of achieving certain outcomes, combination of different sectors to achieve certain outcomes, which was earlier expressed entirely under MKUKUTA II, but I think this idea faded away because of this individualism" *Government official*

Respondents indicated that a clear accountability mechanism would be required to provide some guarantee to those transferring funds to another budgetary authority, either in the form of an accountability framework, or a Memorandum of Understanding (MoU). In addition, previous experiences were shared whereby budgeting guidelines from the Ministry of Finance were modified to enable specific priority budget lines to be built into a specific authority's budget request.

> "whatever method we will use we have to use the mutual accountability framework between the organizations which are working together. It is how everybody becomes accountable to each other and to those ones we are serving. So we should have accountability framework which works." *Government official*

> "So if it is to be done it needs to be not to distance the [paying] stakeholders too much, so whatever sector finally does that, there should be a very close link. Not breathing down their necks, but agree on particular indicators - whether process or impact – that twice a year, four times a year, once a year, whichever is mutually agreeable, to meet and say: are we on track? We are not on track. Why are we not on track? Why aren't we getting these results? Maybe they were the wrong results to look for, let's change, like that. Without that, you become just as… you've given money, but you don't know what has happened." *Government official*

> "just put an MOU to make sure those things are taken into consideration. A risk assessment." *Government official*

> "we can initiate something new, for example, when we were starting the nutrition coordination what we did was to ask the Ministry of Finance to create a special budget line for budgeting nutrition (…) we can also sometimes issue some guideline [to] guide the local government authorities ..." *Government official*

Interviewees from multi-lateral development partners reported being constrained by their roles and/or the division of labour between them and other development partners, which defines what activities or interventions they can invest and engage in.

> "… we also look at areas over which we have mandates, for example, you know as an organisation we are mainly working at policy level, so there are certain interventions which are confined to the policy level, for example the guidelines and things like that" *Multilateral development partner*

> "allocation of resources in [organisation] is based on our core mandate. What is it that we are supposed to provide to the country versus what is it that the other agencies are supposed to provide (…) we've got division of labour" *Multilateral development partner*

The only category of payers at the national level who can be considered pure payers, or purchasers of outcomes, are certain bilateral donors. In the HIV field particularly, bilateral donors reported a very acute outcome focus in recent years, as they increasingly sought to optimise HIV outcomes or targets, subject to their budget constraint alone. Still, even for these 'pure purchasers' there was some underlying sense of an investment constraint along sector lines, and what could be considered something that specific sector's money (e.g. "HIV funding") could be used for.

> "… whatever produces a positive result should really be supported (…) that should be the bottom line." *Multilateral development partner*

> "… [current leadership] is very narrowly focussed, so it's got to be all about the HIV outcome" *Bilateral development partner*

> "the US congress when they put PEPFAR together essentially said this is for HIV funding and HIV funding alone." *Bilateral development partner*

Several national-level decision-makers suggested that in the Tanzanian context of decentralisation by devolution, whereby more resources, fiscal autonomy and responsibility is being decentralised to local government authorities, these sub-national decision-makers may be the least constrained by siloed mandates, given that they are closer to the population and ultimately responsible for the well-being of their constituencies. There may therefore be more potential for co-financing among donors and at the decentralised local government level.

The more common use of service outputs in planning and resource allocation, as well as the service platform constraint that many decision-makers face, suggests that co-financing would only work for national-level government actors if it focuses on the output-level. How co-financing is implemented appears to be a greater issue for collaboration than an unwillingness to share or pool budgets. This could be a potential problem if the cyclical nature of democratic politics means new governments issue new guidance or initiatives on public sector reform.

Respondents suggest they are familiar with new and distinct instruments across sectors, but familiarity does not lead to acceptance or effective means of working and accountability concerns prevail.

5. Lack of budgetary autonomy and loss of control can constrain ability to co-finance

A number of barriers were mentioned by respondents when reflecting on the feasibility and viability of co-financing among government sectors and ministries. Many related to the limited financial autonomy each department or ministry effectively had to reallocate resources, and the very limited discretionary budgets they had to manoeuvre with.

> "Indeed it will be a problem, because the accounting officer for vote 52, which is ministry of health, is the permanent secretary, ministry of health. He is not even accounting officer for certain aspects which goes on for health (…) the money which he is accountable, he cannot transfer to the director of TASAF, so I think these are problems…" *Multilateral development partner*

> "the major challenge is that the resources they get, is not even enough to meet their demand, the normal ones. That is a critical one. For example, in the area of medicine, the area of improving the services in the hospitals, they are crying. They don't have." *Government official*

> "I think in terms of practicality, knowing that they are all getting resources from the same source anyway, and because they have very few resources it is unlikely that once they get allocation they would be willing to share it with another sector." *Bilateral development partner*

Several respondents described institutional disincentives to transfer funds to other budget authorities, because of the loss of budget control it would entail. While co-financing theory assumes that payers want to maximise their outcomes, it became clear that payers can have other objectives, namely to maximise resources under their control. This would invariably lead to resistance to co-financing.

> "resistance, resistance to change, resistance to… I don't know, the typical force field analysis that you would have to do… To bring about, to persuade people who refuse, because they don't think they are going to get money, they don't think they are going to get value, they generally think they are losing power in this area, you know typical institutional fears that would happen." *Multilateral development partner*

Objective concerns were raised around the risks associated with such transfers, related to programme and financial accountability. In terms of programme design, one respondent suggested that if a programme like TASAF would change its targeting criteria, there would be the risk that the benefits to the other paying sectors could be negatively affected. Some also questioned how to ensure that those funds would actually be allocated to the desired intervention, that they would be spent prudently, and that the payer would not be held accountable for any financial misconduct by the implementer. Finally, there would be a risk to

the payer of losing public visibility, and thereby hampering its ability to attract funding in the future.

> "… we will get that money through my department, but if it's their money maybe to channel the resources to go to the sectors, to go to TASAF or what, if you tell the commissioner of budget, don't give me let's say 800 million shillings, give me 700 million shillings, 100 million shillings give it to them. Are you sure they are going to give them? (…) If you are not careful, you can have something and say co-financing and sharing. When we go to scrutinize the budget, we can just cut off the budget, we can say no no no, this is TASAF mandate…" *Government official*

> "…also losing identity, when TASAF goes to village x and provides money, they would never say this comes from [government department]. And resource mobilisation goes with the fact that [government department] has done something and therefore has a good track record of doing x y z… If you just disappear, you provide money and become the ministry of finance. Because nobody thinks of the ministry of finance until budget time. (…) The risk is it may reduce your ability to source and attract other resources." *Government official*

Thus, the perceived barriers and risks to payers contributing to a co-financing scheme were their limited financial authority, constrained budgets and anticipated loss of budget control and visibility, both of which were viewed as fundamental to justifying their very existence.

6. Political will of senior government and development partners overrides feasibility or evidence base

Respondents acknowledged that resource allocation decisions are not a mere act of rational optimisation – they are political decisions, and are evidently influenced by power dynamics, political commitments, the desire by political actors in Tanzania as well as in donor countries to exert their influence and to be visible. Although high-level priorities appeared to be identified through a logical needs and evidence-based process, budget allocations to specific sectors and programmes were more often driven by path dependencies, donor priorities, political agendas and visibility.

> "It is not scientifically based what we contribute in different areas (…) and of course, it also comes in politics in that process, the interest of the government of the time (…) Budget allocation processes are messy, both on our side and the Tanzanian side, and are not fully rational always." *Bilateral development partner*

> "It's more a political decision. They're not looking at (…) which interventions would be more cost-effective or which ones would bring more impact" *Multilateral development partner*

Most respondents underscored the need for strong political will to adopt the approach, embodied in individual 'champions' or 'advocates' for co-financing. Ideally, this 'champion' would need to have convening power to bring multiple government ministries together, preferably in an already established and institutionalised multi-sectoral coordination

mechanism. The sitting administration's narrative around efficiency and cost savings was expected to be opportune to promote such an approach.

> "…of course then you need a strong permanent secretary to say no, we are doing this… So you've got to be, got to be a very strong permanent secretary saying 'bang. I want to do this'…" *Multilateral development partner*

> "I think you would need buy-in at a high level, again going back to your champion. (…) So it will have to have a clear lead, it will have to be very well inbuilt in an ongoing national process, like in a multi-sectorial action plan, where everyone is already convened and agreed to work on, and it would need to be backed up by a solid, very clear analysis of who is getting what and why, and then there has to be a senior decision that cascades down to the others." *Multilateral development partner*

What these responses suggest is that ultimately the mechanisms and feasibility to co-finance are under-pinned by the political will of senior figures and development partners to support the idea. However, as the case of the efficiency argument suggests, the co-financing model can in turn be a source of political will by government and development partner elites should it align with their wider strategic interests.

7. Alternative mechanisms

Some respondents suggested alternative approaches to co-financing that they considered more institutionally feasible. The first involved a situation where a central payer, in this case the Ministry of Finance, would allocate public resources to sectors in a way that incorporates the externalities generated by one for another. After all, several respondents pointed out that there is only one public payer, or as one government official put it: "it is all government money". If this central payer would consider the multiple outcomes of each sector's outputs in their allocation formula, this would be more efficient, could avoid double-counting and the transaction costs of cross-sectoral transfers.

> "I am not sure what is the best way sort of bringing that same good sort of view into these sectors. (…) Each sector have their own money, but actually they don't have their own money, they all depend on one source of money, which is the treasury. (…) your entry point is actually ministry of finance and sort of planning, and saying the new vision is this, this is where we want to go." *Bilateral development partner*

Another related suggestion was that co-financing be used more as a mindset or mentality when considering the value of various investment options, rather than a technical exercise with formulas to calculate co-financing shares. The latter was considered to be "too complex", requiring a "simpler formula in real politics and budget allocations", without "all the gymnastics", as a government official and bilateral development partner put it.

> "One doesn't try to find the formula for the optimal allocation or for one incremental [dollar] what should we invest in one set of priorities… It wouldn't work I think, but that is part of some sort of holistic thinking… Politicians they don't think about that sort of thing. There is some sort of implicit formula in their thinking, in their mind. And also

> bureaucrats. And then they try to find an allocation that makes some sort of sense given what different interventions contribute...” *Bilateral development partner*

A second approach that was mentioned as a viable institutional response to the interlinkages between sectoral programmes and their outputs, was to rely on strengthening coordination through inter-sectoral governance structures. The underlying principle would be to ensure that sectors acknowledge their role in achieving other sectoral outcomes – the premise of mainstreaming. For example, the last of five objectives in the national health sector strategic plan is to address the social determinants of health through a health-in-all-policies approach. An alternative incentive for this coordination is for sectors to coordinate their activities to ensure a better match between supply and demand. For example, TASAF’s cash transfer programme increases demand for health and education services, which needs to be met with available quality services, for the human capital outcomes to be achieved. It is therefore from this perspective that various sectors are being convened at the national and local government level. This appears to be an important mechanism to stimulate communication and dialogue, which appears to be lacking.

> “so if we’re able just to influence polices in other ministries, I think that that would be the most efficient way of dealing with road safety issues that we are putting money, I don’t think we are right in…” *Multilateral development partner*

> “… we convene and explore areas where we can work together to minimize duplication of efforts and see opportunities or avenues that are in one programme or another programme. (…) some sector, because they participated in the design of the programme and they are participating in the implementation, they can easily see where in the cycle of implementation, that sector can intervene with the right intervention. So that we increase the impact of the programme.” *Government official*

> “With the government here, it is even a challenge, even within one sector the different departments don’t talk to each other, even where you think they have a shared objective and a shared strategy, each of these deliver separately and if you take a budget of the sector Ministry, it does not give you a coordinated story of what they are delivering. They don’t even talk to each other in the different sections of the Ministry...” *Bilateral development partner*

Another strand of thinking was that given the challenges in incentivising individuals and sectors to engage actively in such coordination mechanisms, some respondents suggested that a co-financing instrument might be a nudge to an implementing sector of how they can contribute to other sectoral objectives. Indeed, co-financing was viewed by some as a short-term or one-off investment into a programme to enable a programme tweak that would generate other outcomes and ensure that the programme is delivered in this manner going forward. The assumption being that all sectors are jointly contributing to a common set of national social and development goals, rather than each sector being accountable for their own sub-set of objectives.

> "this is just catalytic resources, but at the end of the day we want to see how other sectors can see the bigger picture in this, and sees how the contributions, how the resources lead to better outcomes (…) in general." *Multilateral development partner*

Finally, several examples were given whereby the multi-sectoral outcomes of a programme could be amplified by leveraging the programme platform and financing discrete add-on components. For example, building additional nutrition sensitisation sessions into the TASAF cash transfer delivery.

> "For instance, in the productive social safety net we have a provision of about half an hour before delivering cash benefits, where we administer community sessions. (…) this is an avenue for providing messages. Now, while we provide message on the programme, a nutrition expert can provide message on nutrition. So people have already been mobilized for this programme, so it is just a question of liaising with another sector, with the message for the same people." *Government official*

The suggestion of alternative approaches volunteered by respondents suggests that co-financing is seen as just one method of achieving distinct outcomes in health financing. The results suggest that popular alternatives would be to selectively incorporate some of the co-financing principles into existing processes, either as a mindset shift or a one-off tool to stimulate the new institutional mindset. Hence, while respondents agree that co-financing models are feasible, this does not necessarily mean they are their preferred approach.

8.4 Discussion

This study explored the institutional feasibility of adopting a cross-sectoral or cross-budget co-financing approach for development programmes with multi-sectoral benefits. Insights and perceptions from national government and development partner decision-makers in the HIV, health, social protection and food security sectors in Tanzania suggest that such co-financing may be operationally feasible in a first instance if it focuses on producing service outputs more efficiently (rather than outcomes) and involves payers that directly finance service provision. The voluntary adoption of co-financing is unlikely given several institutional and political factors, unless certain enabling conditions are in place that incentivise and mandate such cost-sharing. However, cost-effectiveness is subsumed to political concerns with government actors assigning political value rather than monetary value to health. Political value in this case refers to the ability to control budgets, divisions of labour across sectors, and the ability to construct or draw upon political will. This section draws on the main results to discuss the barriers and enablers to co-financing, as well as opportunities going forward.

Enablers

The results outlined above suggest a certain level of adaptability and perceived feasibility to adopt co-financing approaches across the Tanzanian public and development sector.

Respondents indicate an openness to reform based on clear evidence of cost savings and improved outcomes (54), with tangible benefits – or win-wins – identified for each of the participating sectors and donors (22). This evidence could be an effective tool for shaping and enabling political will. Co-financing of programmes such as TASAF may enable future co-financing initiatives by first providing evidence of how such models can work effectively in practice, and by initiating a path-dependent model for how government actors can work across sectors. Since multi-sectoral collaboration is embedded within the HIV/AIDS and health response in Tanzania, in principle, there is an ethos of working together. Co-financing could be an extension of such practices.

Aligning co-financing initiatives to existing strategic plans and building the approach into future strategies could enable implementation. Strategic alignment gives capacity and justification for both government and development partner agencies to implement innovative approaches. Because funding and resource allocation is tied to pre-existing mutually agreed strategies and targets, any new financing model must demonstrate how it will help meet wider government and development partner strategies.

In addition, there appears to be more flexibility with mandates and 'instruments' among payers with a strong results and population focus. In particular, donors that are not as constrained by the sectors or services they can invest in, function as pure purchasers of outcomes, and could be attracted to fund programmes with multi-sectoral benefits through a fee-for-outcome mechanism, akin to the results-based financing schemes being rolled out for health facilities (55). Similarly, there may be more potential for cross-sectoral thinking and planning at the decentralised level, where sectoral siloes are less dominant and officials are more population-focused, in line with the experiences with joint budgeting in Sweden and the United Kingdom (16, 21).

Scarcity is another important enabler of co-financing. For the HIV sub-sector in particular, there is definitely a much more acute imperative to prioritise than was the case 5 years ago, when HIV funding appeared abundant (11). In this increasingly constrained context, our findings suggest that evidence has become a more important factor in driving allocations, and there is less room for anything without a hard HIV endpoint. Scarcity may therefore enable more innovative and integrated financing, given the need to do the same or more, with less (26).

Finally, both an enabler and barrier to co-financing programmes is political will. Political will is difficult to quantify and elicit, and is not necessarily based on the same rational economic calculations of cost-effectiveness analysis. It depends on the maintenance of an actor's position (whether Minister, President, or senior advisor, for example) within the Tanzanian government or donor community, and is thus guided by additional motivations. There is ample evidence in the political economy literature indicating that bureaucrats are more likely to be maximising their budgets, and thus their power, than societal outcomes (11, 28). Our data suggests an important political desire and need for visibility by each payer, both to maintain political capital and

mobilise financial resources from government and donors. Such political incentives could directly annul any rationale for co-financing, and resistance to merge or transfer budgets is therefore to be expected. High-level buy-in and political will was a recurrent lever for uptake underlined by the Tanzanian policy-makers (56), who also pointed out that top-down directives may be required to instigate and incentivise co-financing (16).

Barriers

There appear to be several political and institutional barriers that prevent co-financing from happening. Limited government resources and sectoral budgets heighten each budget holder's anxiety and grip over its limited resources. Many budget-holders have limited authority or control over how and where they can spend resources. This reduces their individual autonomy and agency in decision-making and thus ability and will to co-finance. Even though our evidence shows government officials are keen to demonstrate willingness to adopt new, more efficient forms of financing, such will is actioned in a few isolated examples in practice. Evidence in support of feasibility should be treated with caution, given a potential bias towards the subject-matter in interview. Compounded with the scepticism of development partners, it can be argued that while co-financing may be operationally feasible, this is not met with a will to act.

While some constraints could be relaxed by government directives, heavy donor dependence and earmarking of external financing will continue to limit the discretion of these budget holders to re-direct financing to another implementer. Moreover, some donors also appeared reluctant to shift funding towards upstream programmes where accountability and attribution may be more difficult to ascertain and control – possibly reminding them of their problematic experience with general and sectoral budget support (44).

Our findings suggest a mismatch between the co-financing theoretical frame and the decision frames of the decision-makers the approach seeks to inform, particularly for health (57). Co-financing is embedded in health economic evaluation, which focuses on the efficient production of 'health', and has been used in certain high-income countries to influence health care benefits and drugs/treatments covered by national health financing schemes (58). However, our study indicates that service outputs or service coverage are more likely to be the results budgetary authorities are directly accountable for and prioritising against, at least in Tanzania and possibly in other countries without health technology assessment bodies. The other boundary in the optimisation frame underlying co-financing assumes that each payer is constrained only by its budget, whereas our findings indicate that there are in fact additional constraints, chiefly the decision-maker's delivery platform, mandate or its 'instrument'. There is some confusion around sectoral responsibilities and ministerial 'instruments' that tend to be changed by every new president/ administration. This is more likely to encourage more conservative boundaries and financing decisions. Such constraints suggest it may be more fruitful, in a first instance, to refocus the co-financing decision frame around achieving the service outputs of payers more efficiently, making the underlying economic analysis more of a cost minimisation exercise than

an adapted cost-effectiveness analysis. However, even though this may be a more realistic starting point, it would be important to ensure that the concept of opportunity costs of investments remains central to the priority-setting dialogue, and that the link between investment and disinvestment is explicit during the resource allocation process.

Study limitations

This study has several limitations. Firstly, it only reflects the views of a small sample of decision-makers in specific social sectors and financing and planning tiers at the national-level. The dynamics at the sub-national level may be quite different. Secondly, as there were few cases of explicit cross-sectoral co-financing, the insights from respondents were sometimes quite hypothetical, and may not be predictive of actual behaviour or revealed preferences. Thirdly, the role of the researcher, as an economist and an academic, may have led to desirability bias, which could partly explain the emphasis on the role of evidence as a crucial enabling factor (59), although this has not been found to be a consistent factor in other areas of health decision-making in this context (60). Fourthly, the study was conducted in a decisively singular post-election context, characterised by substantial uncertainty about the new government's priorities and some reserve among respondents. The new 'bulldozer' president took office in the first phase of data collection and clearly set out to radically change the government's business-as-usual, transform public work ethics and increase efficiency. This may have led to more openness to new ideas for public service efficiency gains, but may also have restrained government respondents' sense of control.

While the findings from the study are context-specific, they are unlikely to be unique to Tanzania alone. The same development partner organisations, for example, support development programmes across the world, and will be influenced by similar agendas and organisational constraints. Also, governments in high-income countries have had to tackle related barriers and resistance to cross-sectoral coordination and joint budgeting (22).

Policy implications and future research

In practice, there is no central decision-maker with perfect information or the expertise to allocate resources between sectors factoring in all externalities (61). Cross-sectoral co-financing could be a mechanism to internalise these externalities. Given how sectors plan, there are a number of entry points for integrating co-financing approaches at various steps in the planning cycle (62). First, evidence needs to be generated on the value of co-financing mechanisms. More policy experiments with co-financing mechanisms are needed, especially in low and middle-income countries, to investigate their effectiveness at realising efficiency gains and multiplying impact, and to understand where and how they are most likely to be institutionally acceptable. Existing programmes that increase multi-sectoral service outputs, and could generate cost savings for payers through cost-sharing, should be the starting point. This would provide a clear financial incentive for payers to engage in inter-sectoral

collaboration, which previous studies found to be an important determinant of uptake (17, 22). Specific opportunities identified by policy-makers were mainly related to matching complementary demand and supply-side interventions for greater impact. For example, the TASAF programme in Tanzania was an attractive demand-side mechanism to ensure access and utilisation of health and education services, thereby allowing for greater effective coverage. It is also a credible programme, perceived to be low-risk, due to its strong financial management and accountability structures. Such low-hanging fruit could demonstrate the financial gain from co-financing and make it more politically attractive.

Secondly, this learning can feed into future planning, as a key consideration when setting priorities and targets. By valuing multi-sectoral benefits, co-financing can be a means of identifying investment areas that can address multiple objectives, or what is currently known as 'accelerators' in the context of the SDGs. This may shift sectoral allocations, as certain sectoral programmes with large spill over benefits may become more attractive to fund.

Thirdly, at the stage of developing interventions and identifying resources, sectors could proactively seek out investments beyond their sectors that will allow them to meet their sectoral goals. They could then consider extend pooled financing mechanisms to allow for cross-sectoral transfers, or use results-based financing mechanisms to establish fee-for-outcome metrics for all interested payers (63). Clearly, this will have to be preceded by the establishment of a legislative framework that enables cost-sharing across government departments or ministries, as seen in other settings, and followed by a gradual implementation of cross-budget transfers (22).

For the HIV response, the engagement of multi-sectoral stakeholders is diminishing along with HIV financing (11). This has its advantages, as HIV plans appear to be more coherent and prioritised, but it is also becoming more difficult for the HIV sub-sector to convene or stimulate cross-sectoral dialogue and planning, and harder for HIV to get a seat at other sectors' tables. Co-financing could be used to overcome this hurdle and provide catalytic funding to kick-start or tweak multi-benefit interventions implemented beyond the HIV realm. This could be more effective than mainstreaming, as it does not require other sectors to take on an HIV mandate. Indeed, the lack of incentives for other sectors to mainstream HIV is likely to be further compounded by the shrinking HIV funding basket (64), unless these resources are used more strategically.

Indeed, while the principles of joined-up government and integrated approaches are generally well-received, experience suggests that accepting the mindset or 'ethos' is not sufficient and may be counter-productive if political agendas and values are invisibilised in the process rather than being tackled head on (23). Tying a financing mechanism to the inter-sectoral collaboration may be a means to make the expectations of various stakeholders explicit and a tool to hold each other accountable.

This could be of increasing relevance within the new global development agenda, which underscores the importance of synergistic action across SDGs. Resources to achieve the SDGs are currently spread out among diverse actors and constrained by systems of public and private finance and development assistance that may not be fit for purpose (65). Co-financing approaches may contribute to re-engineering intersectoral governance and financing mechanisms to match the challenges ahead (25, 66).

Another area for further investigation that was underscored by this study, is the fundamental question (and potential inefficiency) of who is responsible for maximising health gain overall, if it is not the national health payer or the health care sector. Current decision frameworks assume that the sectoral budgets are allocated to services rather than to outcomes, i.e. the national 'health' budget is a reflection of society's willingness to pay for health care services rather than its willingness to pay for health. In practice, and in an attempt to reflect a "decision-maker's" approach (67), this is how economic evaluation in health is applied, with a myopic focus on health care (35, 37). As Culyer (1989) states: "health services are needed (…) only if the outcome is desired and there is no alternative (or more cost-effective) way of realizing it" (68). The premise of co-financing is that it could be a means to expand the evaluative space and decision frame if there is in fact a more cost-effective way of achieving the health outcome through cost-sharing, than the most efficient health care intervention.

Determining who is responsible for 'health' is critical, if the public sector is to efficiently contribute to the production of better population health. If countries decide that the mandate to maximise health gain lies with the health sector, rather than with a central supra-ministerial payer, then constraints of which services or interventions they can fund need to be relaxed, and disciplinary identity boundaries will need to be breached.

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CHAPTER 9 DISCUSSION AND CONCLUSION

This last chapter will summarise the main findings of the thesis under each of the study objectives, reflect on its limitations, and discuss its contribution to the literature. Finally, the key policy implications from the research will be discussed, together with a forward-looking research agenda.

This thesis sought to tackle the challenges associated with economically evaluating and financing interventions with multiple outcomes valued by multiple sectors. Conventionally, cost-benefit analysis is the recommended method to value multiple benefits, but given the monetary utility measure of outcome, and the dominant extra-welfarist viewpoint in health, this approach is not often embraced by the health and certain other social sectors. To address this, alternative multidimensional outcome measures of well-being are being developed. However, even with such a measure, the question remains of who should finance an intervention that increases overall well-being through various sectoral pathways and mechanisms, when in practice, there are multiple payers with distinct budget constraints and priorities.

To address this gap, the aim of this thesis was to develop and explore the application of a novel methodological approach for both fiscal space analysis and economic evaluation that explicitly factors in multiple intervention benefits *and* multi-sectoral payers. The thesis research focused on structural HIV interventions that are delivered outside the conventional HIV sub-sector and achieve multiple HIV and non-HIV impacts. The underlying premise was that methodological developments were required to adequately consider these interventions when answering two distinct questions: what is the available resource envelope (fiscal space) for the societal goal of reducing HIV morbidity and mortality, and how can the fixed HIV budget be most efficiently (cost-effectively) allocated to achieve this goal? These questions have become increasingly central in global and national HIV responses that are being confronted with the binding constraints of their sub-sector and biomedical emphasis, as well as having multiple funding streams and budget constraints to contend with.

This thesis set out to achieve the following objectives:

1. To develop a methodological approach – ‘co-financing’ - for factoring in non-HIV benefits and non-HIV payers in the decision rules of resource allocation;
2. To explore the potential of creating fiscal space for HIV across sub-Saharan Africa, incorporating co-financing of health system strengthening and broader development investments;
3. To apply the co-financing approach by assessing the benefits and potential of co-financing of a food support intervention in various country settings;

4. To understand in practice the institutional barriers, enablers and (dis)incentives to adopting a co-financing framework in HIV financing and priority setting.

Objective 1 was addressed in Chapters 4 and 5, while the following three objectives were covered in each of the subsequent results chapters (5-8).

9.1 Main Findings

9.1.1 To develop a new methodological approach that factors in non-HIV benefits and payers

The first objective of this thesis was to develop a methodological approach to economic evaluation and financing that incorporates non-HIV benefits and non-HIV payers.

In the HIV and public health fields, cost-effectiveness or cost-utility analyses tend to be the dominant decision-analytical tools for investment decisions. As highlighted in the literature review in Chapter 2, a well-documented limitation of cost-effectiveness analysis is its inability to deal with multiple outcomes and cross-sectoral costs and consequences, given its underlying single outcome framework (1, 2).

The conventional approach to evaluating interventions with multiple benefits is a cost-benefit analysis (CBA), which converts all outcomes into a single monetary measure of utility, and allows for cross-sector comparisons of investment alternatives (1, 3-6). However, it has been strongly argued that utility is a problematic and potentially undesirable proxy measure of social welfare, as it only reflects individual satisfaction that is derived from the consumption of goods and services (7).

Another recommended approach for considering multiple benefits in an economic evaluation and investment decision is to conduct some form of cost-consequence analysis (CCA), which reports the different consequences of an intervention in natural units, alongside the costs (8). The purpose of a CCA is to present decision-makers with all relevant impacts and costs across sectors, including those that could not be quantified or monetised, in order to enable them to appraise the full value of the intervention options. Indeed, current guidance on the economic evaluation of health interventions requires a disaggregated cost-consequence approach when analysing and reporting results (8, 9). However, CCA does not provide a measure of relative efficiency that would allow for some form of intervention ranking.

Neither of these methods addresses how costs would be shared between payers for interventions with multiple outcomes, which has been underscored as a methodological gap in current guidance documents, including the National Institute for Health and Care Excellence's (NICE) guidance for local government decisions in England and Wales, and the second US panel's recommendations on cost-effectiveness analysis in health and medicine (8, 10). Claxton and colleagues' so-called 'compensation test' is the only method identified that deals with both multiple benefits and their multiple payers (or budget constraints) (11). It suggests that the normative decision rule for such interventions would be that if other benefiting sectors can compensate the implementing sector for its net cost, then the intervention should be funded.

As described in Chapter 4, this thesis builds on this compensation principle, and proposes a so-called co-financing approach, as an analytical prioritisation tool and a financing mechanism. Indeed, co-financing would require an actual financial transfer mechanism to be in place, rather than merely an analytical test to determine whether an intervention is worth investing in from a social welfare perspective. It thereby overcomes an underlying limitation of the 'compensation test', which implicitly ascribes non-health mandates and objectives to a health payer (and vice versa).

The example of a cash transfer intervention for adolescent girls that was implemented in Malawi with HIV, education and other health outcomes (12), was used to illustrate with empirical data how a co-financing approach could lead to a more optimal financing outcome than the current status quo of budgeting in silos.

The basis for the allocation of co-financing shares was the willingness-to-pay (WTP) by each sector for the achievement of one unit of their sector-specific outcome. For the health outcomes, we used normative cost-effectiveness thresholds stipulated by WHO, as a measure of opportunity cost (13, 14). An HIV payer, a reproductive health payer, and a mental health payer, were each willing to pay one to three times Malawi's GDP per capita for one Disability-Adjusted Life Year (DALY) averted through improvements in their health indicators. For the education outcomes, estimates of cost-effectiveness ratios from other studies in the region were used as positive measures of revealed WTP. The one-way sensitivity analysis underscored how much the financing outcome, and efficiency-enhancing potential of co-financing, would depend on the WTP threshold applied. Although the health WTP threshold appeared to have relatively broad recognition, these WHO thresholds have been increasingly critiqued for not reflecting the opportunity cost or the shadow price of the health budget constraint (13, 15, 16), and even WHO has since distanced itself from them (17).

Chapter 5 further develops the co-financing approach in the context of emerging scholarly debates and consensus around the meaning and measurement of these cost-effectiveness thresholds. Culyer's bookshelf metaphor (18) is used to illustrate how current unisectoral approaches to

resource allocation could result in health losses, particularly when considering health-producing interventions in other sectors or public health interventions with multi-sectoral outcomes. Based on a stylised two-sector model in which health and education budgets are being optimised, the inefficiency of silo budgeting is reflected as health and education losses from having separate evaluative spaces. In this case, the health cost-effectiveness threshold may be lower than the health care perspective would suggest. The chapter then demonstrates the advantages of a second best co-financing approach, where the health payer could redistribute part of its budget to a non-health sector, where co-financed non-health interventions achieved a health gain more efficiently than the health sector's marginal productivity (opportunity cost). Likewise, other sectors would determine how much to contribute towards such an intervention, given the current marginal productivity of their budgets.

Whereas Chapter 4 estimates the potential efficiency gains from a co-financing approach in the context of an endogenous budget constraint, Chapter 5 considers that the sectoral budgets are exogenous and fixed. Indeed, in Chapter 4, the financing outcome from the CBA is assumed to be optimal, and the welfare loss associated with maintaining the status quo is derived from the net benefit that would have otherwise been achieved. Yet, the CBA uses a do-nothing comparator and its decision rule requires that any intervention that grows the social welfare 'pie' (where benefits exceed costs) should be funded, even if this means increasing the budget constraint. Chapter 5, on the other hand, applies an opportunity-based approach where the investment alternative is the least efficient current intervention. Any new investment would therefore displace the latter and need to be compared against its foregone benefits. The latter is likely to be more consistent with the decision-maker's perspective, and a better reflection of each payer's decision problem.

The proposed co-financing approach is a step forward in addressing the limitations of cost-effectiveness analysis, as identified by Coast (7), without representing a departure from the guiding frame of extra-welfarism and its evaluative space. It also provides a potentially practical approach to dealing with an important limitation concerning the allocation of costs between budgetary authorities jointly benefiting from an intervention (8, 10).

9.1.2 To conceptualise and apply the analytical tool to estimating the resource envelope

The second objective of this thesis was to explore the potential of creating fiscal space for HIV through co-financing of health system strengthening and broader development investments. This was part of both method development for fiscal space analysis, and exploring method applicability.

Chapter 6 reports a fiscal space analysis estimating the sources of domestic financing for HIV in 14 sub-Saharan African countries. In addition to traditional sources of fiscal space, such as economic growth, expanded revenue generation, borrowing and reprioritisation, the analysis also included measures of efficiency gains within the HIV programme, as well as cost savings from investments beyond the HIV envelope. While previous analyses implicitly assumed that less prioritisation of the HIV programme would reduce fiscal space for HIV (19, 20), this analysis explored the potential HIV gains from reprioritisation towards investments in other areas of spending that benefit HIV.

Drawing on econometric methods, this chapter estimates the monetary value or the implied shadow price of the effect of non-HIV programme targets on the HIV programme's level of output (21). The analysis specifies a model of HIV service production, and uses this to calculate how much extra HIV spending would be required to reach the same level of HIV programme output, as would be achieved by increasing the number of health personnel to the WHO target or reducing undernourishment to the MDG target level.

The analysis suggests that substantial efficiency gains could be reaped from more effective complementary investments in health systems and social development, particularly in low-income countries. Indeed, in the six selected low-income countries with high HIV burdens, it was estimated that about USD 230 million could be saved annually in direct HIV spending over the next 5 years, if the ratio of health professionals to the population was increased to the WHO norm. This represented a much greater magnitude of potential fiscal space than the USD 9 million expected from economic growth alone or the USD 66 million from efficiency gains in the ART programme. Likewise, reductions in undernourishment to the MDG target level could save USD 136 million in annual HIV spending, which is not far from the USD 149 million in additional fiscal space from a steep increase in HIV prioritisation in the national health budget.

In these resource-constrained settings, the opportunity cost of increased HIV financing may be particularly high and synergistic investments all the more important. Based on this, the HIV budget holder may find financial value in contributing to the expansion of human resources for health or reduced undernourishment, to avert the need for direct HIV expenditures. Although HIV financing has been channelled toward health systems (22-24), some argue that the HIV sector has made only marginal short-term investments in complementary health system inputs, and that these could be reaching their limits (25). This chapter suggests that it may be more rational for HIV budget holders to consider co-investing more systemically in these binding constraints, such as pre-service training and recruitment of health personnel or improvements in supply chain management (25, 26). This may be particularly beneficial in resource-limited settings where the return from jointly investing in these non-HIV constraints may be higher, given that the so-called marginal rate of

technical substitution between financial and non-financial production inputs is likely to diminish as the availability of non-HIV inputs increases.

In summary, this analysis shows the maximum gain in terms of increased funding for the HIV response from adopting a co-financing approach to investment choices, and getting the scheme in place. The viability of the approach will depend on the total costs of the non-HIV investments required, the availability of sufficient non-HIV resources to cover part of these costs, and the transaction costs of establishing and managing the co-financing scheme.

9.1.3 To apply the analytical tool to assessing how to spend the envelope most efficiently

The third objective of this thesis was to apply the co-financing approach as an analytical prioritisation tool in country-level analyses, by assessing the costs, benefits and potential of co-financing a food support intervention aimed at improving HIV and food security outcomes. This serves as a proof-of-concept of the feasibility of applying this approach as an economic evaluation technique.

Chapter 7 presents this study component, in which the economic returns of a 6-month food assistance intervention for food-insecure patients initiating ART were estimated in 5 sub-Saharan African countries (Tanzania, Zambia, Ethiopia, Lesotho and South Africa). Impact data from a randomised controlled trial in Tanzania (27) was used and supplemented with a costing analysis and an economic evaluation model. The analysis was conducted from a health care perspective, as well as a multi-sectoral perspective, as recommended by current international guidance (8, 9). The latter was extended to incorporate a co-financing approach to the valuation of the multi-sectoral outcomes.

The findings suggest that targeted food assistance could be a cost-effective complementary intervention for HIV treatment programmes, particularly if the evidence on the effects of food assistance on ART adherence and loss-to-follow-up from Tanzania are generalizable to these other settings and if the intervention costs are minimised. Considering its potential short-term impact on household food security, targeted food assistance may also be valued by the social protection sector and therefore co-financed, further increasing its HIV-specific cost-effectiveness, and thus bringing it up in a ranking list of HIV interventions. Indeed, assuming a conservative cost-effectiveness threshold per DALY averted of half of each country's GDP per capita (28), the findings indicate that, with the exception of Lesotho, this intervention is likely to be cost-effective in the selected countries, both with and without co-financing. In Tanzania, Zambia and Ethiopia, the

probability that the intervention would be cost-effective ranges from 65% to 81% without co-financing, and increases by up to 6 percentage points with co-financing to between 71% and 84%. For South Africa, co-financing would not alter the probability of cost-effectiveness, which remains at 92%. However, co-financing could affect the financing decision in Lesotho, where the intervention becomes marginally more likely to be cost-effective than its comparator with co-financing (53%), compared to without (49%).

Overall, if resource decisions are driven by assessments of cost-effectiveness, the findings suggest that it may not always be necessary to pursue co-financing options for such intervention components that are added on to basic HIV programmes to enhance their effectiveness (HIV+ type interventions), and that co-financing investments may be of most importance to supporting development synergy type interventions that are primarily aimed at achieving non-HIV objectives (DEV type interventions presented in Chapter 3) (29).

The delivery platforms used for food and nutrition support are particularly important, because they reflect financing channels and budget holders. The intervention could be delivered as a broader social protection programme, with an add-on HIV component that would ensure that food-insecure PLHIV initiating ART were targeted. The cost to be co-financed may then only be the incremental variable cost of reaching this sub-population. Alternatively, if food support was to be delivered through the HIV programme and primarily viewed as an add-on component of the ART programme, it would be the incremental cost of providing food assistance through health facilities that would need to be co-financed. In this research, the costing was done from the latter perspective. When exploring what level of co-financing contribution would be warranted from the HIV payer if this were programmatically delivered through the ART programme, it was clear that most of the direct costs would be expected to be covered by the HIV budget in Zambia (60%), Tanzania (73%), and Ethiopia (83%). However, in South Africa, only about 40% of direct intervention costs would remain to be covered by the HIV programme, after deducting the social protection sector's share. In fact, it would probably be good value for money and could potentially be practically feasible for the HIV payer to only pay the unit costs of the food provided to HIV patients in the case of South Africa (i.e. about a third of the direct intervention cost), as well as part of the operational mark-up, but rely on the social protection budget to cover the remaining operational costs of delivery.

Although Chapter 7 demonstrates that the co-financing approach can be applied to assess the value for money of specific multi-benefit interventions, it also underlines the methodological challenges in doing so. Given the often narrow focus of impact evaluations, there is limited data on the non-health impact of health interventions, or health impact of non-health interventions (30). It ensues that the scope of the consequences considered in a multi-sectoral or societal economic evaluation is likely to be driven by the availability of data (or lack therefore), rather than by theory and plausibility of effects. The same shortcoming has been observed in applications of cost-benefit

analysis (31). In addition, the application of the co-financing methodology requires the estimation of a cost-effectiveness threshold for each non-health outcome, which is meant to capture the opportunity cost to the non-health payer of investing in the intervention being assessed. There is a severe lack of data to inform this and it was necessary therefore to use data from an unsystematic search of interventions in the non-health sector with the same food security outcome, to roughly estimate the cost-effectiveness ratio of the social protection payer's assumed alternative investment. The resulting uncertainty around this parameter was at least partly addressed with robust sensitivity analyses.

9.1.4 To understand the institutional feasibility of co-financing as a financing mechanism

The fourth objective of the thesis was to understand in practice the institutional barriers, enablers and (dis)incentives to adopting a co-financing framework in HIV resource allocation. This forms part of the study's exploration of the proposed method's applicability as a financing mechanism.

Chapter 8 discusses the thesis' qualitative study component that explored the institutional feasibility of adopting a cross-sectoral or cross-budget financing approach for development programmes with multi-sectoral benefits, in the context of HIV. While there is evidence of modest uptake and implementation of co-financing or joint budgeting modalities, the literature remains fairly limited, with examples being skewed towards high-income countries (32-34). A series of key informant interviews were conducted with national government and development partner budget holders in the HIV, health, social protection and food security sectors in Tanzania.

Insights and perceptions from these respondents suggest that co-financing may be feasible, under certain conditions, and with adaptations to the underlying framework. However, respondents stressed that even when there is a strong co-financing case to be made, they expected that its operationalisation would be hampered by political incentives and the institutional culture of the health sector and the civil service.

The findings underscored how real-world decision frames are markedly different from the theoretical frame used in health economic evaluation and thus co-financing. The underlying assumptions that decision-makers are maximising sectoral outcomes, and that this is done subject to a budget constraint alone, is overly simplistic. Rather, to the extent to which optimising rationalities are guiding resource allocation at all, the reality is that payers are more likely to be optimising service outputs and coverage. Prioritisation between service outputs tends to be driven by global targets and the availability of certain earmarked funding streams. In addition to the budget

constraint, payers also face other constraints or boundaries, namely the decision-maker's delivery platform or its so-called 'instrument'.

Given these additional institutional parameters, findings suggest that in practice co-financing may initially be more viable as a cost minimisation strategy, if payers allocate resources beyond their delivery platforms as a means of achieving the same service output at a lower cost through another sector's intervention. This may be particularly relevant for matching supply and demand-side interventions, as with the example that was mentioned of using the national cash transfer programme as a mechanism to increase enrolment rates in the voluntary community-based health insurance scheme, rather than spending health sector resources on health insurance sensitisation campaigns. It would allow for a pragmatic consideration of service uptake constraints that originate in other sectors, rather than assuming that they do not exist (35).

Several specific enablers were identified by the study participants. Compelling evidence of multi-sectoral impacts and expected cost savings were consistently highlighted as being potentially influential. This has also been found in previous studies on joint budgeting (32, 36). Another important lever for uptake that was brought forward was strong political will and some form of top-down directive mandating a co-financing scheme. Although high-level buy-in and champions will undoubtedly be vital, the literature suggests an important trade-off between the sustainability of co-financing and top-down mandatory schemes that may increase sectoral resistance (32).

Findings from the Tanzanian context further indicate that there may more flexibility with mandates and 'instruments' among payers with a strong results and population focus. In particular, donors that are not constrained by the sectors or services they can invest in, could function as pure purchasers of outcomes, and could potentially be attracted to fund programmes with multi-sectoral benefits in their own right, or through a fee-for-output or outcome mechanism, akin to the results-based financing schemes being rolled out for health facilities (37). Similarly, respondents appeared to suggest that there could be more potential for cross-sectoral thinking and planning at the decentralised level, where sectoral siloes are less dominant and officials are more focused on delivering benefits to particular populations – as has been the case with joint budgeting in Sweden and the United Kingdom (38, 39).

The study results suggest that the implementation of co-financing approaches may often not be straightforward, even when there is a strong economic justification for it. Limited resources and budgets could very well heighten each budget holder's anxiety and grip over its limited resources, especially if these decision-makers are more likely to be maximising their budgets than social welfare, as argued in political economy theories (40, 41). Moreover, in Tanzania, the limited budgetary autonomy that many decision-makers effectively had over largely earmarked resources would further constrain the feasibility of reallocations towards cross-sectoral co-financing.

9.2 Contribution to knowledge

This thesis makes a key contribution to methods to value and finance health-enhancing interventions in non-health sectors. The proposed co-financing approach tackles the challenge of attribution of costs for interventions with multiple benefits and payers, which has been highlighted as an important methodological gap in economic evaluation (8, 10, 42). Although it is increasingly recognised that health economic evaluation needs to consider non-health consequences, current guidance remains silent on how a health payer should value consequences outside the sector, in order to decide on the most judicious allocation of its resources (8). In England and Wales, for example, NICE guidance further acknowledges the lack of a standard method to apportion costs when more than one government department or local government is involved in delivering an intervention or is reaping its benefits (10, 43).

The most relevant evaluation method for such interventions was Claxton and colleagues' 'compensation test' (11), which proposed hypothetical compensation between sectors as an analytical tool, but discarded actual intersectoral transfers. In the domain of health promotion financing, and the integration of health and social care, there is a parallel literature on joint budgeting experiments that have been implemented to overcome the inefficiencies of siloed planning and resource allocation (32, 34). The contribution of this thesis is therefore to link the theoretical framework of hypothetical cross-sectoral compensation together with the experience of co-financing or pooled budgeting, and to apply the approach to empirical case studies in low-income countries and in the context of HIV.

Compared to other solutions that have been proposed to address the challenge of incorporating multiple benefits and payers, the co-financing approach appears to provide more internal consistency with the dominant health economic evaluation framework, and to have more potential for operationalisation as an institutional financing mechanism. Indeed, analysts grappling with this in the fields of social care and environmental economics are leaning towards a cost-benefit analysis framework that monetises non-health outcomes. For example, Wildman and colleagues propose a hybrid economic evaluation technique for social care interventions with health and social outcomes, that would monetise health outcomes using the cost-effectiveness threshold, while adopting WTP elicitation methods to monetise the social outcomes (44). Due to the blended frameworks, this approach could have a higher risk of double-counting benefits, and could be misleading. In the environmental field, there has been a general reliance on CBA and more consistent efforts to identify and value co-benefits, but this has been done more as an advocacy strategy to make the investment case for policy intervention, rather than as a means of informing resource allocation (45, 46). In the literature on fiscal federalism, it is suggested that a centralised budget could provide matching grants to decentralised fiscal authorities as a mechanism to internalise positive

externalities (47), which is somewhat similar to the principle of sectoral budgets matching each other's budgets for this purpose.

An important strength of this thesis is that it drew on various strands of the economic literature, including health economics, new institutional economics, political economy, and public finance, to understand and identify potential solutions to a common analytical challenge with partial equilibrium analysis that sectors tend to take, and to a financing challenge for siloed public policy. The programme of inquiry is also strengthened by its mixed methods approach, combining economic evaluation, econometric analysis, and qualitative in-depth interviews. This allowed for a more rounded analysis of the potential of co-financing as an efficiency-enhancing strategy, going beyond the theoretical method development to real-world application and the exploration of institutional feasibility. In addition, findings on the reality of decision-making were subsequently utilised to reflect on and reframe the co-financing decision space.

9.3 Limitations

As discussed in more depth in relevant chapters, the thesis and the methodology it proposes have a number of limitations that are worth noting. The limitations of the analytical co-financing approach are covered first, followed by the caveats around the findings on the value and applicability of the approach, given the methodological weaknesses of each study component and the methods applied.

First, the proposed co-financing approach is embedded in an extra-welfarist framework, and assumes that all sectors adopt a similar decision frame. As discussed in Chapter 5, its focus is on societal objectives (such as population health), rather than aggregate individual utility, and the source of valuation is based on the efficiency of the current allocation, rather than individual preferences (18, 48, 49). This multiple payer approach further implies that each sector has a utilitarian objective of maximising a specific benefit, even though this does not necessarily reflect sectoral or societal values, and may not be the framework of choice in other non-health sectors, where welfarism and cost-benefit analyses may dominate (46, 50-52). There may be other risks within this extra-welfarist approach, since it does not question the current intersectoral allocation of overall resources and may over-rely on the biases and judgment of decision-makers (11, 52). However, assuming that individuals are the best judges of their and society's well-being is also arguable, especially for areas like population health (53).

Moreover, although the approach takes a broader cross-sectoral perspective to inform resource allocation decisions, it is greatly skewed towards a provider perspective and the efficiency of the

allocation of sectoral budgets that may tend to ignore the costs incurred by patients or consumers, unless those costs were substituting expenditures that would normally fall on the provider's budget constraint (9). Related to this, the decision frame adopted when each sector or payer considers whether to co-finance an intervention is likely to require different comparators depending on how the intervention would be delivered, and what its implementation would be incremental to. This issue was highlighted in Chapter 7, where the intervention costing adopted a health sector perspective, whereas the implementation could have been through the social protection sector, in which case the incremental costs are likely to have differed. While most of these limitations relate to the underlying theoretical framework adopted, they can also be addressed by explicitly considering and deliberating on them when defining the decision problem and scope.

Second, when assessing the most efficient use of a fixed budget, it is important to factor in that certain outcomes may be endogenous to others and there is a risk of double-counting. While co-financing makes the simplistic assumption that education budgets are used to maximise education outcomes, and health budgets are used to maximise health outcomes, evidence suggests that education outcomes have downstream impacts on health outcomes and vice versa. Importantly, the allocation of the budget to the education sector may already be made, in part, on the basis of its contribution to health, in which case transferring part of the health budget on this basis could cause inefficiencies. This could be more important when considering sectoral budget allocations, where compound effects may be factors that have influenced and continue to guide allocations (54). Indeed, the education budget is often justified in relation to its expected benefits for economic productivity (55). On the other hand, a full consideration of all interactions in the long-term is likely to be too complex and impractical to operationalise. Decisions about financing interventions that deliver multi-sectoral benefits in the short-term could be more pragmatically assessed with this simplifying assumption that sectors are optimising separate mutually-exclusive outcomes.

Third, using co-financing as an analytical approach is potentially very data-hungry and its results could be particularly sensitive to data availability. Evidence of impact and cost would be required across sectors, as well as data on the marginal productivity of each sector's budget, or its cost-effectiveness threshold. Moreover, the estimation of co-financing shares will depend on which outcome measures were evaluated for a given intervention, and on the data available on the costs and impact of other existing investments in each sector. Indeed, the fewer benefits considered, the higher each payer's share. The data and analytical demands of estimating cost-effectiveness thresholds across multiple payers, as well as the costs of conducting multiple outcome evaluations, may prohibit the realisation of such an efficiency-enhancing co-financing mechanism. As a starting point, interdisciplinary evaluation approaches building on an evidence-based theory of change could be a way to ensure that the most plausible benefits are captured (31), and to determine the expected value of having this additional information (56).

Clearly, there are several methodological caveats around the co-financing approach developed and whether it could be applied and operationalised. Rather than being an indictment of the approach, however, many of these limitations simply underscore the need for further methodological development and optimisation, as well as the importance of a carefully considered and policy-orientated decision frame.

Further key limitations in the applications of the co-financing approach in this thesis include the limited attention to transaction costs and non-health costs, the issue of endogeneity in the fiscal space analysis, data availability and quality for the quantitative analyses, and the context-specificity of the qualitative analysis. Indeed, the transaction costs of pooling budgets and reaching a coordinated outcome were not considered or quantified in the analyses. Yet, co-financing would only be able to generate efficiency gains if the additional benefits or the cost savings from pooled financing, would outweigh the transaction costs of coordination (57, 58).

Moreover, there was a focus on non-health outcomes and much less on intersectoral costs resulting from an intervention. Evidently, these are equally important when taking a co-financing approach and exploring the use of cross-sectoral transfers, based on each sector's net cost and net benefit. Conversely, a recent review on how economic evaluations have been incorporating a broader societal perspective reported that more attention is typically given to intersectoral costs (mainly productivity costs), which are more easily monetised, than to outcomes that are difficult to value (59). The inclusion of the former can have important implications for the results of an economic evaluation, particularly in certain disease areas, such as mental health programmes and their spill over cost consequences in the criminal justice sector for example (60). This limitation may have led to an over- or underestimation of different sectors co-financing shares estimated in Chapter 4 and 7. For example, in the co-financing analysis of the cash transfer intervention in Malawi, the increase in school attendance would have had some resource implications for the education sector to provide services to more girls, but these costs were not estimated and would have reduced the education sector's net benefit and thus contribution to the direct intervention costs. The omitted non-health sector costs resulting from the food support intervention for people initiating ART are less evident and may have been less important for the co-financing outcome.

Another limitation when using co-financing principles to consider the resource envelope, as done in Chapter 6, was that there may be concerns around endogeneity. It is not unreasonable to expect that while sectoral expenditures drive outcomes, the level of outcome achievement may also drive resource allocation and sectoral spending. Similarly, the level of output, or in this case HIV service coverage, could affect the non-HIV inputs, including the number of health personnel and the level of undernourishment in the population, particularly in high burden countries. There may also be omitted variables that influence both expenditures and outcomes, as well as non-HIV inputs and coverage, but are difficult to control for. There are therefore limitations in the econometric methods

that were used to explore how investments in non-HIV programmes could generate cost savings for the HIV budget. The potential efficiency gains from co-financing may have been overestimated for investments in human resources for health and reduced food insecurity. That being said, there is a relatively stronger theoretical case for this direction of causality, especially for the former, with consistent observational data that suggests that a production function for health service coverage includes exogenous human resource inputs (61, 62).

The availability and quality of the data used to conduct the economic evaluation modelling in Chapter 7, in particular, was not without its shortcomings. It relied on the results from two separate trials to model effectiveness for HIV and food security outcomes, and then required extrapolations of effects and costs between country settings. This was mitigated by considering a broader range of studies in a probabilistic sensitivity analysis, which still indicated likely scope and benefits from co-financing.

Finally, although this thesis investigated the institutional incentives, enablers and barriers to the adoption of a co-financing framework at the national level in Tanzania, certain political and institutional factors identified are likely to be context-specific. Similar challenges, barriers and resistance to cross-sectoral coordination and joint budgeting have been documented among governments in high-income countries, and some aspects are likely to be generalizable to other contexts (32). Moreover, many of the same development partner organisations support programmes across the world, and are individually likely to be influenced by similar agendas and organisational constraints from their respective central levels.

9.4 Policy implications and Future research

The findings from this study have implications for policy and for future areas of research.

While the HIV response has tasked itself with ending the epidemic as a public health threat by 2030, and is focusing heavily on the 90-90-90 targets to ramp up effective treatment coverage, it continues to face serious constraints to service uptake and adherence as a result of structural factors (63). Despite earlier enthusiasm on ‘treating our way out’ of the epidemic, results from biomedical prevention and test-and-treat trials consistently point to the limits of this approach (64, 65). Yet, the limited evidence base on the effectiveness of structural interventions, and their relatively high cost per HIV outcome, have made HIV payers reluctant to invest in them. Cross-sectoral co-financing provides an *analytical* solution to prevent their undervaluation in value for money assessments, which would ensure that more of these options make their way into the HIV toolbox as interventions to be considered. In addition, the approach offers a *financing* solution to

make these interventions more financially viable for the HIV response, as well as other payers interested in social development goals. Whereas the HIV sub-sector's appetite for financing structural interventions was previously low, the new context of relative funding scarcity may make innovative and integrated financing more attractive (66-68).

Calls and initiatives for 'joined-up government' or 'whole-of-government' approaches are emerging in many areas of public policy. Like HIV mainstreaming, the agenda of Health-in-All-Policies further aims to mandate non-health sectors to take on more proactive roles in achieving health gains (38). Successes in promoting this have been insufficient, however, and the entrenched sector-based institutional incentives may partly explain this (69). Co-financing could be used as a financial incentive to enable more policy integration and coherence (67). HIV funders could also use it to provide catalytic funding to kick-start or tweak multi-benefit interventions implemented beyond the HIV realm. This would not require other sectors to take on an HIV mandate, and could therefore be more effective than mainstreaming by aligning cross-sectoral objectives (70).

In the context of the 17 highly interconnected Sustainable Development Goals (SDGs), there is an evident need to think differently about development programmes, and to recognise the importance of cross-sectoral synergies and joint action. Some goals and targets are indivisible, or at least reinforcing or enabling, meaning that investments in one of these areas could deliver benefits across multiple targets (71). Reducing hunger and chronic malnourishment, for example, would be necessary to the goal of ending poverty and would contribute to quality education for all. However, there are also other areas where investments to achieve one goal or target could be at the expense of another. Promoting food production may negatively affect ecosystem protection or climate change mitigation efforts (71). Yet, resources to achieve the SDGs are currently spread out among diverse actors and constrained by systems of public and private finance and development assistance that may not be fit for purpose (72). Policy-makers continue to operate in silos and lack the tools to identify the most important interactions across sectoral targets, and thus opportunities to maximise positive interactions and minimise negative ones. A framework has been developed to support sectoral policy-makers to take mutually-reinforcing actions and minimise or better negotiate trade-offs (71). Co-financing approaches could contribute to re-engineering intersectoral governance, planning and financing mechanisms to match resource allocations to the identified programmatic areas that can accelerate the achievement of multiple goals and targets (73-75).

Based on the research in this thesis, it is recommended that policy-makers seek to identify co-financing opportunities, and focus efforts on areas and programmes where the undervaluation is expected to be most acute, and the potential gains from pooled budgets most likely to offset the transaction costs. Existing experience suggests that there may be more potential for this at decentralised levels of government, where siloes are less pronounced and objectives more population-focussed, rather than sector-focussed (32).

There are also certain policy risks that come with the promotion of a co-financing approach to fund upstream structural interventions with HIV and health impacts. The first is the risk of any efficiency-enhancing strategy, namely that it will become an excuse for reduced overall financing. Specifically for co-financing, which recognises the linkages between social development objectives, it is important to not end up pitching social sectors against each other, but rather to argue for the consideration of co-benefits to increase the overall social budget. The second policy risk of highlighting the social determinants of health, is the possibility of ending up in a trickle-down paradigm (76), whereby economic development will be the upstream goal, with downstream benefits for education, health and social well-being. In the context of HIV, it is possible that once structural interventions are explicitly seen as relevant HIV investments, politicians could claim that several of their development investments are HIV-related, giving them room to manoeuvre to decrease HIV-specific investments, or conversely, that if there is a case to be made for other sectors to pay for structural interventions, the HIV budget could end up being more tightly earmarked for 'core' HIV programming, at the expense of investments in add-on enabling interventions.

There is ample ground for future research in this area. Indeed, this thesis aimed to develop a new method and explore its applicability. It has provided some initial applications of the co-financing approach in economic evaluation in low-income countries. Others have since referred to the approach in their economic analyses of HIV programmes (77), and the co-financing mechanism has been identified as an innovative modality to be used in the implementation of national strategic plans for HIV and social protection (in South Africa and in Tanzania) (78, 79). However, the methodological approach is still in its infancy and requires further optimisation and standardisation. This would involve standardised analytical guidance aligned to and embedded within existing international guidance on conducting and reporting economic evaluations in global health (9), with a particular focus on how analysts should define the decision frames of each payers, given that they may have different comparators, objective functions and constraints. It would also be beneficial to apply the approach to other diseases and health areas that are likely to benefit from multi-sectoral action, such as cholera control, nutrition, the prevention of intimate partner violence, among others (80-82).

In addition, this thesis provides evidence to inform further methodological optimisation that reflects real-world decision-making, and to inform the implementation and assessment of the financing mechanism. Although the co-financing model has been tested in a few European countries with mixed results (32, 36), prospective testing and evaluation of these models in low and middle-income countries would be required, both from an efficiency perspective, as well as a political economy perspective. These would need to examine whether co-financing or joint budgeting

models have generated cost savings across sectors, and if so, whether these are greater than the associated transaction costs of coordination. In addition, further policy analysis would need to ascertain in what institutional contexts co-financing mechanisms are most likely to succeed or fail, and what pre-conditions could improve the likelihood of success.

Some of the required data inputs for conducting a co-financing analysis are seriously lacking, and further research would be a prerequisite to the feasibility of the approach going forward. Indeed, the lack of evidence on the multiple outcomes of interventions resulting from the siloed approach to impact and economic evaluation needs to be addressed. Intersectoral evaluations should become the norm for public health interventions and non-health interventions that target key established social determinants of health, such as education, water and sanitation, nutrition and food security, and gender-based violence, especially in settings where such programmes appear to be underfunded. These evaluations should be driven by clear theories of change and theory-based assessments of the likely cross-sectoral costs and consequences of policy interventions (7, 42, 59). However, in cases where it is not feasible or too costly to conduct robust intersectoral evaluations, it will be important to have a larger body of evidence on the relationships between different risk factors and health benefits, to enable the modelling of health outcomes in the economic evaluation of non-health interventions.

Moreover, the theoretical basis for co-financing shares should be each budget's shadow price, or cost-effectiveness threshold. Although there is some burgeoning empirical research in the health field to 'search' for this threshold (83, 84), it is important that these efforts are extended beyond the UK and beyond the health sector, if decisions are to be based on positive measures of marginal productivity. This will only happen with strong policy demand for and subsequent use of such measures in priority-setting.

Although the thesis adds to the literature on the theoretical frameworks and approaches to resource allocation between and within sectors, it also raises several questions that are not specific to the multi-sectoral perspective taken. First of all, it highlights a dissonance between the adoption and acceptance of a welfarist framework to establishing resource envelopes (fiscal space) between sectors, and an extra-welfarist framework to optimising the use of some of these budgets. There appears to be some emerging consensus in the scholarly debate around cost-effectiveness thresholds and the use of willingness-to-pay methods. Whereas the welfarist concept of WTP per health outcome (e.g. QALY or DALY) is accepted as relevant to setting the health budget, or determining the 'consumption value of health' (16, 18, 84) (– or rather health *care*) vis-à-vis the consumption of other sector goods and services; an extra-welfarist measure of marginal productivity of the health budget is considered most appropriate for efficient allocations to health

interventions. Yet, when considering a multi-sectoral framework, it becomes clear that this can only yield efficient outcomes if there is equivalence between aggregate individual utility derived from the consumption of all public sector goods and services, and the sum of all the sectors' outcome measures valued by their opportunity costs. This is unlikely to be the case, given that utility and extra-welfarist measures, such as those considered in health, are fundamentally different measures of welfare. Sen's capabilities' approach has emerged as a viable and more comprehensive alternative to defining and measuring social welfare (7). Significant efforts are being made to develop multidimensional measures of capabilities and well-being that can be used to capture a range of socially desirable outcomes, and could potentially bridge these two approaches, if embraced across sectors as a primary measure for resource allocation (85). That being said, the latter is unlikely in the near future, and further investigation might explore the consequences and potential perverse incentives of some sectors optimising based on sector-specific outcomes, while others optimise based on utility.

Finally, the thesis highlights that the scope of the decision problem for economic evaluation may need to be rethought, since there is a disconnect between the implicit optimization problem and the decision space of policy-makers these analyses are seeking to inform. The current evaluative space defines a single health decision-maker seeking to optimise health gain subject to a health budget alone, although this 'health payer' actually faces an additional constraint in terms of what types of interventions it can invest in, making it a 'health care payer'. This raises the fundamental question (and potential inefficiency) of who is responsible for maximising health gain overall, if it is not the national health payer/ministry of health or the health care sector. This must be tackled if the public sector is to efficiently contribute to the production of better population health. If countries decide that the mandate to maximise health gain lies with the health sector, rather than with a central supra-ministerial payer, then constraints of which services or interventions they can fund need to be relaxed, and disciplinary identity boundaries will need to be overcome.

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APPENDIX 1

ZOMBA CASH TRANSFER TRIAL

The Zomba trial was implemented by the World Bank from January 2008 to December 2009. This randomised controlled trial is described in detail elsewhere [1]. All never-married girls aged 13-22 at the end of 2007 in a random sample of 176 enumeration areas in the rural district of Zomba, Malawi were invited to take part in the trial. Of these, 3,796 were enrolled at baseline, of which 1,225 were randomised to the treatment group and were offered monthly cash transfers. The majority (789) were already in school at baseline while the others were girls that had dropped out of school (436). Among the baseline schoolgirls, 506 were randomised to the conditional arm, whereby their receipt of the monthly cash transfer was dependent on their 80% school attendance. The unconditional arm received the cash regardless of their attendance.

Methods for estimating the Willingness to Pay

In order to estimate how much each sector would be willing to pay for this intervention, we started by determining which (sub-)sectors would be interested in the first place, based on which outcomes were found to be significantly impacted by the intervention. Various reports from the trial provided evidence that the intervention had statistically significant impacts on prevalent HIV, prevalent HSV-2, school enrolment, English test scores, school drop-out rates, pregnancy rates and cases of depression. We therefore consider that the HIV budget holder, the sexual and reproductive health budget holder, the mental health budget holder and the education budget holder would see value in investing in such an intervention.

Table S1. Sample sizes of Control and intervention groups and Intervention cost estimates

Participants in Control Group	**Amount**	**Source**
Schoolgirls Only	1495	[1]
Dropouts Only	453	[1]
Total Participants	1948	[1]
Participants in Intervention Group		
Dropout Pooled	436	[1]
Schoolgirl Pooled	789	[1]
Schoolgirl Unconditional Only	283	[1]
Schoolgirl Conditional Only	506	[1]
Total Participants	1225	[1]
Intervention Cost (2009 US$)		
Cost per Pupil (Lower Estimate)	$90[1]	[2]

[1] Assumes more reasonable administrative costs at scale (excluding the trial costs) and reducing the average cash payment amount to US$ 5 per month, which Baird and colleagues estimated could be achieved without affecting the intervention's impact (Baird et al., 2012).

Cost per Pupil (Upper Estimate)	$225	[2]
Total Intervention Cost (Lower Estimate)	$110,250	Cost per pupil x Total girls in Intervention group
Total Intervention Cost (Upper Estimate)	$275,625	Cost per pupil x Total girls in Intervention group

Since we equate willingness to pay (WTP) per (sub-)sector with sector-specific normative or positive thresholds, we first need to estimate the intervention's impact in absolute terms and in the units of outcome for which thresholds exist. For all health outcomes, we therefore need to estimate impact in DALYs, which can be derived from infections/cases averted. For education outcomes, we found that cost-effectiveness ratios exist for enrolment in percentage, additional years of schooling, drop-outs averted, and 0.1 standard deviations in test scores. We therefore calculated absolute impact for these indicators, using the percentage-point difference between control and treatment groups and multiplying by the size of the sample in the trial. For the HIV, HSV-2 and teenage pregnancy outcomes, we used the unweighted percentage-point difference, rather than the weighted percentages estimated by the authors, as a more conservative estimate [3-5], but we also conduct a sensitivity analysis using the weighted ones.

It is important to note that the effect was only significant for certain treatment groups, i.e. school girls that were in school at baseline, girls that had dropped out of school at baseline, or only among baseline school girls in the conditional arm. We only applied the impact to the specific sample for which it was significant, as shown in Table 4.

Identification of lower and upper bound WTP thresholds in the education literature

We used the review of cost-effective education interventions in developing countries conducted by J-PAL for school attendance. Findings are summarised on their website, at the following link: http://www.povertyactionlab.org/policy-lessons/education/student-participation. Four interventions are included for Africa, namely information on returns to education for parents (Madagascar); deworming through primary schools (Kenya); free primary school uniforms (Kenya); and merit scholarships for girls (Kenya). Each intervention's cost-effectiveness ratio is presented as the number of additional years of school participation obtained per US$ 100 spent. We translated this in a cost per additional year of participation ($100/CER). A member of J-PAL informed us that these were in 2010 US$, so we deflated the costs to 2009 US$ using the United States 2009 inflation rate World Bank (World Development Indicators)[6]. We used the lowest CER as the lowest WTP for an additional year of schooling and the highest CER as the highest WTP, i.e. providing parents with information on the returns to education and merit scholarships for girls respectively.

For school enrolment and test scores, we adopted the review by Evans and Ghosh (2006)[7] as a starting point. From this review, we retained and reviewed studies evaluating interventions that were implemented in sub-Saharan African countries had the lowest and the highest cost-

effectiveness ratio. For test scores, we used the CER figures reported in Evans and Ghosh (2006) for studies with randomised designs, since they were expressed in the same unit (0.1 standard deviation gain) as what we had calculated for the Zomba trial. We kept the CERs that adjusted for the deadweight loss associated with the intervention.

For school enrolment, we selected and reviewed in detail the studies from Sub-Saharan Africa with the lowest (Glick & Sahn, 2005) and highest CER (Handa, 2002), including non-randomised designs (there was only one study with a randomised design from SSA). Glick & Sahn (2005) modelled the cost-effectiveness of school consolidation with multigrade elimination, which had the lowest CER expressed per additional student enrolled (translated from Malgashy francs to US$ based on the 1994 exchange rate reported in the study).

For Handa (2002), the highest estimated CER that the authors concluded was worth considering was for another supply-side intervention consisting of the construction of additional schools to improve accessibility (70 schools per province). The total cost was estimated at US$ 49 million (assumed 1998 US$). The projected enrolment gain was 13%, but the authors did not indicate how much this represented in absolute numbers of additional students enrolled. We used data from the other intervention modelled in the paper to deduce the total primary school age population under consideration. For the adult literacy intervention, the authors indicate that there are 490,000 illiterate household heads are in the bottom quartile, which represent 59% of all households in this quartile). We therefore calculate that there are 490,000/0.59 x 4= 3,322,033 households in total. In the survey sample of 8,250 households, there were 2,293 (girls) and 2,203 (boys), or 4,496 children, between 7 and 11 years old – the primary school age. The ratio of households to students was therefore used to estimate the total number of school aged children targeted with the school construction intervention, i.e. 3,322,033/1.835= 1,810,408. The 13% increase in enrolment in this population therefore corresponded to an additional 235,353 children enrolled, or a CER of US$ 208 (1998 US$).

In terms of drop-outs averted, we only found one study with this measure and programme costs, i.e. Duflo et al (2006), which evaluated an intervention in Kenya to reduce the costs of primary schooling by providing free uniforms. This intervention is also considered above for additional years of schooling. The study reported a reduction in drop-out rates among girls from 12.4% to 9.9%. It benefited an average of 28 girls in 328 schools, or 9,184 girls in total. The reduction in drop-out thus corresponds to 230 female drop-outs averted. At a total cost of US$ 93,152 (=284 per school in 328 schools), this represent a cost per drop-out averted of US$ 406 (2005US$).

All the CERs from these reviews were adjusted to 2009 US$ using the United States inflation rates from the World Bank (World Development Indicators)[6]. Where the year of the currency was unclear, we assumed that it was for the year before the study was submitted for publication (Handa, 2002) or published (Duflo et al, 2006).

Finally, all CERs in 2009 US$ were adjusted to Malawi using the ratio of the CER to the 2009 GDP per capita of the country in which the intervention was implemented [6]. For example, the

cost per drop-out averted of 2009 US$ 455 in Kenya (Duflo et al, 2006) represented 60% of Kenya's 2009 GDP per capita of US$755 in 2009 US$; or US$ 204 in Malawi (59% of Malawi's 2009 GDP per capita US$339).

Conversion of health outcomes to DALY

We estimated the health outcomes of the Zomba trial in the following natural units: HIV infections averted, HSV-2 infections averted, teen pregnancies averted and depression cases averted. Since the WHO cost-effectiveness thresholds that we use are for costs per DALY averted, we had to translate these into DALY equivalents.

For HIV infections averted, we estimated the associated DALYs, based on standard DALY formulae [8] and parameters relevant for the target population, with both a no ART and a full ART scenario (see Table 3). We estimate 25.76 DALYs per HIV infection in a no ART scenario and 15.66 DALYs per HIV infection in a scenario with full ART coverage. We use the latter more conservative estimate in our analysis.

Table S2. DALY Parameters [9]

Parameters	Value	Source
Age-weighting modulation constant	1	Murray et al, 2006[8]
Discount rate	3%	Murray et al, 2006[8]
Age weighting constant	0.04	Murray et al, 2006[8]
Adjustment constant for age-weights	0.1658	Murray et al, 2006[8]
Disability weight pre- AIDS	0.221	Salomon et al, 2012[10]
Disability weight AIDS – no ART	0.547	Salomon et al, 2012[10]
Disability weight AIDS receiving ART	0.053	Salomon et al, 2012[10]
Duration pre-AIDS	8 years	Hogan et al, 2005[11]
Duration ART	13 years	Cleary et al, 2008[12]
Duration AIDS (no ART)	2.9 years	Cleary et al, 2008[12]
Age of onset of HIV (ART)	16 years	Baird et al, 2012[1]
Disability weight major depressive disorder – mild episode	0.159	Salomon et al, 2012[10]
Disability weight major depressive disorder – moderate episode	0.406	Salomon et al, 2012[10]
Disability weight major depressive disorder – severe episode	0.655	Salomon et al, 2012[10]
Duration of an untreated depressive episode	0.5 year	Chisholm et al, 2004[13]
Lifetime suicide risk for affective disorders, ages 15-45	9%	Chisholm et al, 2004[13]
Weighting of mild untreated depressive episodes	30%	Chisholm et al, 2004[13]

Parameters	Value	Source
Weighting of moderate untreated depressive episodes	47%	Chisholm et al, 2004[13]
Weighting of severe untreated depressive episodes	23%	Chisholm et al, 2004[13]
Expectation of life at 15-19, females, Malawi, 2011	49.77	WHO life tables[14]
Expectation of life at 25-29, females, Malawi, 2011	40.90	WHO life tables[14]
Expectation of life at 35-39, females, Malawi, 2011	34.22	WHO life tables[14]
Age at onset of depressive episode	15 years	Baird et al, 2012[1]

DALYs associated with cases of depression were estimated in the same way, with specific depression parameters from the 2004 WHO CHOICE exercise [13] and the latest Global Burden of Disease study [8]. We assume that 91% of cases of depression will consist of a single untreated episode of 6 months (weighted to include mild, moderate and severe episodes), followed by full recovery and no loss of life. This is conservative as it excludes remission, which is known to be quite high. For the remaining 9%, we assume that the 6-month episode will be severe and end in suicide. This may be an overestimate of years of life lost, since 9% is the lifetime suicide risk in this age group, not the risk per episode. Nonetheless, we estimate 34.77 DALYs in 9% of cases and 0.31 DALYs in 91% of cases, or a weighted average of 3.41 DALYs per depressive disorder.

For teen pregnancies, we estimated DALY equivalents from the second edition of the Disease Control Priorities Project. We used the figures reported for family planning, with a US$ 131 per birth averted in sub-Saharan Africa corresponding to US$ 34 per DALY averted [15], or 3.8 DALYs per birth averted. This does not appear unreasonable given Malawi's high maternal and infant mortality rates, as well as increased risks among young adolescent women [16, 17].

In terms of HSV-2 infections averted, we decided to use a very conservative estimate from a high-income setting [18], which only considers the psychosocial adult morbidity of genital herpes psychosocial, leading to lower mental health scores. This excludes potential sequelae from meningitis, erythema multiforme and neonatal herpes [19], for lack of data parameters. Also, to avoid double-counting, we do not take into account the cofactor effect of HSV-2 on HIV transmission [20]. In Canada, it was estimated that the cost per case of genital herpes averted through screening would be $8,200. Based on the quality of life weights derived from this study, authors estimate that this would correspond to $140,000 per quality-adjusted life year gained [18]. We consider that this corresponds to 0.06 QALYs per genital herpes infection and convert this directly to 0.06 DALYs per HSV-2 infection.

Cost-benefit modelling assumptions for the fair share approach

The WTP estimates in the above were used as equivalents of monetised HIV benefits (HIV DALYs averted x WTP threshold of GDP per capita). The other long-term benefits of such an intervention were modelled by adopting the benefit-cost ratio from a previous study (King et al., 2007) that estimated the costs and benefits of conditional cash transfers to young women. For every US$ 1 invested, between US$ 3.49 and US$ 26.12 could be generated in benefits through increased future earnings and DALYs averted from child mortality, under various discount rate assumptions (3% and 5%) and DALY value assumptions (US$ 1,000 and $5,000).

For consistency, we monetised HIV DALYs in the base case at US$ 1,000 and included the higher valuation of $5,000 in the sensitivity analysis.

In addition, on the cost side, we deducted the cost savings from averted antiretroviral treatment. The discounted lifetime ART costs of 2002 US$9,435 or 2009 US$11,303 were taken from a South African study [21]. Fifty percent of the costs were considered drug-related and therefore internationally comparable (not adjusted) and the other 50% were adjusted to Malawian prices, based on the ratio of Malawi's GDP per capita to South Africa's GDP per capita (i.e. US$ 5,511 per person on treatment or US$ 35,966 for the 6 HIV infections averted by the trial).

Welfare Loss Calculation

Welfare loss was calculated for the silo approach as the net benefit that could be achieved from implementing the intervention. The total benefits were the net intervention benefits of US$ 478,373 plus the HIV treatment cost savings (US$ 35,966). The implementation costs (US$ 110,250) were deducted from this total of US$ 514,338 to estimate the net benefit of US$404,088.

Table S3. Detailed inputs and data sources

(Sub-)Sector	Outcome metric	Impacted group	Control	Treatment	Gain	Source	DALYs per unit (health)	Source	Conversion to DALYs averted	WTP per unit (min)	Source	WTP per unit (max)	Source
Education	Drop-outs re-enrolled (additional student enrolled)	All baseline drop-outs	12.3%	56.6%	193	[1]	Not applicable			16.81	[22]	220.42	[23]
	Years of full school attendance	Baseline schoolgirls conditional arm	80.1%	90.2%	77[2]	[24]				3.91	[25]	163.33	[25]
	English test scores 0.1 standard deviations gained		n.a.	0.14 higher than control	708	[24]				1.54	[7]	3.29	[7]
	Drop-outs averted	All baseline schoolgirls	83.5%	86.6%	24	[26]				16.81	[22]	204.45	[27]
HIV	HIV infections averted	All baseline schoolgirls	2.13%	1.43%	6	[1]	15.6	See above	83	339*	[6]	1,017†	[6]
Mental health	Depression cases averted	All baseline schoolgirls	24.5%	18.7%	46	[28]	3.41	See above	10	339*	[6]	1,017†	[6]
Sexual & Reproductive Health	Teen pregnancies averted	Baseline schoolgirls unconditional arm	4.23%	0.75%	10	[1]	3.8	See above	38	339*	[6]	1,017†	[6]
	HSV-2 infections averted	All baseline schoolgirls	3.00%	1.02%	16	[1]	0.06	See above	78	339*	[6]	1,017†	[6]
Health sub-total									208				

** Malawi GDP per capita in 2009 (adjusted to 2009 US$ with United States inflation measured by GDP deflator) from World Bank's World Development Indicator. † 3 times Malawi's 2009 GDP per capita*

[2] 51 additional full years of schooling in conditional arm (506*0.902-506*0.801) over 18 months of implementation (1.5 years) = 77 additional years of schooling.

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APPENDIX 2

1 Data Sources

Table S1.1. Data description

Indicator name	Definition	Date Extracted	Year	Source
Gross domestic product per capita, current prices (U.S. dollars)	GDP is expressed in current U.S. dollars per person. Data are derived by first converting GDP in national currency to U.S. dollars and then dividing it by total population.	2014-05-15	2008-2012	IMF (International Monetary Fund)
Adult HIV Prevalence (%)	Percentage of the population aged 15 and above living with HIV.	2014-06-10	2008-2012	AIDS Info Online Database
Total HIV spending by funding source (U.S. dollars)	Sum of Domestic Public, International and Private Spending.	2014-12-09	2008-2012	AIDS Info Online Database
Domestic Public HIV spending (U.S. dollars)	Expenditures in-country that originated from public sources (authors' definition for lack of definition on AIDSinfo) Note: countries may be reporting expenditures made by public agents	2014-12-09	2008-2012	AIDS Info Online Database United Republic of Tanzania: PER 2012 and then inflated to 2013
Domestic International HIV spending (U.S. dollars)	Expenditures in-country that originated from international sources (authors' definition for lack of definition on AIDSinfo) Note: countries may be reporting expenditures by international actors	2014-12-09	2008-2012	AIDS Info Online Database United Republic of Tanzania: PER 2012 and then inflated to 2013
Domestic Private HIV spending (U.S. dollars)	Expenditures in-country that originated from public sources (authors' definition for lack of definition on AIDSinfo)	2014-12-09	2008-2012	AIDS Info Online Database
Control of corruption	Reflects perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests. Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance). Re-scaled to [2.5; 7.5].	2014-05-14	2012	The Worldwide Governance Indicators (WGI)

Indicator name	Definition	Date Extracted	Year	Source
Number of people living with HIV	Total number of people living with HIV (adults and children)	2014-09-06	2010-2012	AIDS Info Online Database
Revenue excluding Grants (% GDP)	Revenue is cash receipts from taxes, social contributions, and other revenues such as fines, fees, rent, and income from property or sales. Grants are also considered as revenue but are excluded here.	2014-05-12	2010-2012	International Monetary Fund, Government Finance Statistics Yearbook and data files, and World Bank and OECD GDP estimates. Catalog Sources World Development Indicators. IMF regional economic outlook reports or IMF staff review reports CIA Fact book (Cuba, Venezuela)
General government gross debt (% GDP)	Gross debt consists of all liabilities that require payment or payments of interest and/or principal by the debtor to the creditor at a date or dates in the future. This includes debt liabilities in the form of SDRs, currency and deposits, debt securities, loans, insurance, pensions and standardized guarantee schemes, and other accounts payable. Thus, all liabilities in the GFSM 2001 system are debt, except for equity and investment fund shares and financial derivatives and employee stock options. Debt can be valued at current market, nominal, or face values	2014-07-01	2012	International Monetary Fund, World Economic and Financial Surveys, World Economic Outlook Database, October 2012.
General Government Health Expenditure (% General Government Expenditure)	General government expenditure includes consolidated direct outlays and indirect outlays (e.g. subsidies to producers, transfers to households), including capital of all levels of government, social security institutions, autonomous bodies, and other extra budgetary funds. General government expenditure on health comprises the direct outlays earmarked for the enhancement of the health status of the population and/or the distribution of medical care goods and services among population by the following financing agents: central/federal, state/provincial/regional, and local/municipal authorities; extra budgetary agencies, social security schemes; parastatals. All can be financed through domestic funds or through external resources.	2014-05-12	2012	WHO (World Health Organisation) -Global Health Expenditure Database Zimbabwe: MoF "Estimates of Expenditure for the year ending December 31, 2012"

Indicator name	Definition	Date Extracted	Year	Source
General Government Expenditure (% GDP)	General government expenditure (GGE) includes consolidated direct outlays and indirect outlays, such as subsidies and transfers, including capital, of all levels of government social security institutions, autonomous bodies, and other extra budgetary funds.	2014-05-12	2012	WHO (World Health Organisation) -Global Health Expenditure Database
Out of pocket per capita	Household out-of-pocket spending (OOPs): the direct outlays of households, including gratuities and in-kind payments made to health practitioners and to suppliers of pharmaceuticals, therapeutic appliances and other goods and services. This includes household direct payments to public and private providers of health care services, non-profit institutions, and non-reimbursable cost sharing, such as deductibles, copayments and fee for services	2014-05-12	2012	WHO (World Health Organisation) -Global Health Expenditure Database Zimbabwe: Health Systems 2020 report (2010): https://www.hfgproject.org/wp-content/uploads/2015/02/Zimbabwe_Health_System_Assessment20101.pdf
Excise tax as a per cent of the retail price of alcoholic beverages (Beer)	The alcohol excise tax is indicated as a % of the retail price of beer.	2015-12-22	2012	WHO (World Health Organisation) Global Health Observatory data repository Nigeria:from government source: https://www.customs.gov.ng/Guidelines/Excise/
Domestic Public and International HIV spending on Care and Treatment (U.S. Dollars)		2012-09-03	2008-2012	AIDS Info Online Database
Non-drug cost per person on treatment (minus average drug costs from literature)	Cost per Person on Treatment minus 2012 USD 132, from Tagar et al (2014)[1].	2014-09-14	2008-2012	Calculated using the following indicators Cost per person on treatment (calculated using International HIV spending by programme area-US$ Care & Treatment and Population)
People receiving antiretroviral therapy (Number)	Estimated number of people receiving ART	2014-06-06	2008-2012	AIDS Info Online Database

Indicator name	Definition	Date Extracted	Year	Source
Proportion of Public HIV Spending to GGHE in US dollars	Domestic Public HIV spending (U.S. dollars) divided by General Government Health Expenditure (U.S dollars)	2014-05-12	2012	Calculated using the following indicators Domestic Public HIV spending (U.S. dollars) General Government Health Expenditure (U.S dollars)
Nurse density	Number of nursing and midwifery personnel per 1000 population	2014-05-12 2014-10-07	2007-2012	Global Health Observatory of the World Health Organization World Bank World Development Indicators Africa Health Workforce Observatory http://www.who.int/whosis/whostat/EN_WHS09_Table6.pdf
Pregnant women tested for HIV, estimated coverage (%)	Percentage of pregnant women who were tested for HIV during the last 12 months.	2014-11-18	2010	Global Health Observatory of the World Health Organization
Adult literacy rate, population 15+ years, female (%)	Percentage of female population aged 15 years and over who can both read and write with understanding a short simple statement on his/her everyday life	2014-11-18 15:28	2008-2012 2007	UNESCO UIS INFORMATION PAPER-June 2013 for Democratic Republic of the Congo, Ethiopia, Kenya, Liberia, Namibia and Zambia
Undernourished (% of total population)	A state, lasting for at least one year, of inability to acquire enough food, defined as a level of food intake insufficient to meet dietary energy requirements.	2014-10-28	2010-2012	FAOSTAT (Food Agriculture Organization of the United Nations)
Inflation, GDP deflator (annual %)	Inflation as measured by the annual growth rate of the GDP implicit deflator shows the rate of price change in the economy as a whole. The GDP implicit deflator is the ratio of GDP in current local currency to GDP in constant local currency.	2014-02-09	2008-2012	World Bank national accounts data, and OECD National Accounts data files. Catalog Sources World Development Indicators

Indicator name	Definition	Date Extracted	Year	Source
Population (Total)	Total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship -- except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin. The values shown are midyear estimates.	2014-05-14	2008-2012	World Bank national accounts data, and OECD National Accounts data files. Catalog Sources World Development Indicators
Urban population (% of total)	Urban population refers to people living in urban areas as defined by national statistical offices.	2014-06-20	2012	World Bank national accounts data, and OECD National Accounts data. Catalog Sources World Development Indicators

2 Financing Data for 14 focus SSA countries

Table S2.1. Financing Data for 14 focus SSA countries

Variable	Botswana	Ethiopia	Kenya	Lesotho	Malawi	Mozambique	Namibia	Nigeria	South Africa	Swaziland	Uganda	United Republic of Tanzania	Zambia	Zimbabwe
Public HIV Spending per PLHIV	923	33	85	148	2	9	799	35	337	155	31	5	14	25
GDP per person	9,407	471	994	1,340	270	652	5,635	1,654	7,636	3,119	574	650	1,486	858
HIV Prevalence	23.0%	1.3%	6.1%	23.1%	10.8%	11.1%	13.3%	3.1%	17.9%	26.5%	7.2%	5.1%	12.7%	14.7%
Control of Corruption	5.94	4.4	3.9	5.11	4.55	4.41	5.32	3.87	4.85	4.67	4.05	4.15	4.64	3.73
International HIV spending per person	281	254	334	112	103	161	517	128	48	223	207	187	235	161
Year of spending data	2011	2008	2012	2008	2008	2012	2010	2012	2009	2009	2008	2011	2012	2012
Government revenue, excl. grants as % GDP	35.8%	14.0%	23.2%	57.5%	26.0%	23.3%	32.5%	25.3%	28.3%	36.4%	13.4%	17.5%	21.0%	28.0%
Gross government debt as % GDP	15.0%	22.2%	47.2%	41.6%	49.0%	42.0%	27.2%	14.7%	41.2%	22.0%	36.2%	46.8%	28.0%	61.5%
Government Health Expenditure as % Government Expenditure	8.0%	11.1%	5.9%	14.5%	17.8%	8.8%	13.9%	6.7%	12.9%	18.1%	10.2%	10.2%	16.4%	8.6%
Out-of-pocket expenditure per person	21	7	21	20	3	2	32	62	47	28	22	13	23	n.a.
Alcohol excise tax, as % retail price (beer)	40%	50%	n.a.	n.a.	9%	n.a.	n.a.	20%	35%	24%	60%	7.75%	n.a.	n.a.
Non-drug cost per person on ART	1,394	559	571	1,154	70	422	1,581	395	2,009	431	1,346	737	131	137
Public HIV spending as % of GHE	69.0%	3.4%	18.2%	19.2%	0.7%	2.5%	25.5%	2.4%	12.0%	12.1%	9.2%	0.8%	1.8%	9.7%

3 Normative approach to estimating Fiscal space

We follow similar methods as other fiscal space assessments, modelling normative assumptions through for each of the sources of fiscal space to estimate the public finance that could be generated and allocated to HIV, other things held constant (*ceteris paribus*).

We estimate the potential increase in public spending for HIV in selected countries from a ***conducive macroeconomic environment*** based on the IMF projected GDP growth between 2014 and 2018, assuming that this will lead to an equivalent percentage increase in HIV spending. Next, we estimate the same potential increase from increased government revenues (excluding grants) as a share of GDP to an empirical average of 25%[2].

In terms of ***reprioritisation***, we estimate how much additional HIV financing would result from increasing the prioritisation of health in the government budget to the Abuja target of 15% (assuming a pro rata increase for HIV spending, even though it is not all health-related). In addition, we consider how much more public spending would be if its share of government health expenditure would increase to 0.5 times the ratio of HIV Disability-Adjusted Life Years (DALYs) in total DALYs[3].

To account for the option of ***deficit financing***, we consider an increase of the debt to GDP ratio to the 40% 'prudent' level, according to the IMF, and estimate the equivalent increase in HIV spending.

In terms of ***sector-specific resources***, we use out-of-pocket expenditure as a proxy of the potential to improve revenue generation through *risk-pooling* of private resources for health under a tax-based or social health insurance scheme, and estimate how much could potentially be mobilised if OOP were reduced to an acceptable level of 20%, which minimises catastrophic health expenditures[4] and 50% of the rest would be redirected from the private sector to a government-managed risk-pooling social health insurance scheme. We deducted USD 1.77 as the estimated per capita cost of administrating a national risk-pooling scheme[5]. The current share of HIV spending in total health spending is used to apportion those resources to HIV.

We also consider potential fiscal space for HIV if an *earmarked alcohol tax* were to be added to the existing tax, bringing it up to the 50% maximum stipulated by a directive by the West and Central African Monetary Union[6]. Reduced sales from the price increase are deducted from the total additional revenue using a -0.3 price elasticity of demand[7-8]. No incremental administrative costs were factored in, since it would just be an increased amount taxed on existing sales that are already taxed.

Finally, we estimate potential **efficiency gains** in treatment and care programmes, by calculating the approximate cost per person receiving ARVs and retained in care (total treatment and care spending / (number of people receiving ARVs x retention rate)) as a ratio of GDP per capita, after deducting internationally priced (first-line) drug costs of USD 132 per person on treatment (2012 USD)[1]. We use this measure to identify the best performing country per income category (low income; lower middle income; upper middle income). Combined with the results from the empirical study by Menzies et al (2012) that found a logarithmic relationship between non-drug ART unit costs and per capita GDP, and

an average increase of 22% in non-drug unit costs for each doubling in per capita GDP[9], we estimate logarithmic functions as the 'efficiency frontier' functions for each income category. The 'optimal' non-drug ART unit cost per country is then used to estimate potential savings in the ART programme, and that proportion of savings is applied to public HIV spending. We used constant number of people on ARVs in the next 5 years as a conservative estimate.

All estimates in total US$ were divided by the average number of adults living with HIV (above 15 years) per country in 2013 (for current) and over the next 5 years to yield public spending per adult living HIV. We used estimates of the number of PLHIV per country over the period 2014-2018 produced from STDSIM under a scenario of continued current coverage rates and treatment eligibility of CD4 count below 500 mm[10]. We could not do this for Botswana, Lesotho, Swaziland and Namibia, as they were not included in the STDSIM modelling, so we used a constant number of total people living with HIV from UNAIDS Aidsinfo (2013).

All estimates were calculated in Excel spreadsheets.

Sensitivity Analyses for Technical Efficiency gains

Given the complexity of measuring HIV programme technical efficiency and the relatively simple measure used, we conducted three sensitivity analyses to explore the sensitivity of the results to (a) the pace at which the efficiencies can be realised; (b) the choice of the best performers, i.e. the efficiency frontier; and (c) the functional form (see Table S4).

a) To take into account a more gradual realisation of efficiency gains over the 5 year period, we used empirical site-level data to spread the efficiency gains over the 5 year period. Menzies et al (2012) find that ART programme maturity drives non-drug costs, with large drops seen in the first year (41%), followed by considerable reductions in the second year (25%)[9]. Given our 5 year timeframe and assuming that the reduction from the third year on drops to a further 10% (our assumption), we could expect an overall reduction of 68% between year 5 and year 1. The first year reduction in total treatment and care costs in our sample ranges from 13% (Malawi) to 85% (Uganda), with an average of 47%. However, in our base case analysis, we estimate that these reductions are achieved in the first year and sustained for 4 more years. Here we spread the first year reduction in costs over the 5 year period, based on the empirical figures above. Hence, 60% of the savings are achieved in the first year, another 22% in the second year, followed by an additional 6% for years 3-5. With this approach, we estimate 15% lower annual average efficiency gains per country.

b) We changed the best performers to the best performer of all low-income, lower-middle income and upper-middle income sub-Saharan African countries, rather than countries within the subset of 14 countries. For the low-income countries, the best performer became Chad, for lower-middle-income countries it remained Zambia, and for upper-middle-income countries it became Gabon. In this case, total average efficiency gains would double, driven by the much larger potential for the 3 upper-middle-income countries.

c) We assume a linear relationship between the ratio of non-drug ART unit costs to GDP per capita, instead of a logarithmic one. This would mean that a given country could achieve the same ratio as the best performer in their income category. With this approach, average efficiency gains would be 27% higher.

Table S3.1. Potential sources of domestic financing in selected countries in sub-Saharan Africa based on the normative approach

	Current Public HIV spending per adult living with HIV (US$)	Average Additional Public HIV Spending per adult living with HIV (2014-2018 annualised, US$)								Maximum potential Public HIV Spending per adult living with HIV (US$)	Average HIV savings from non-HIV spending per adult living with HIV (2014-18, annualised, US$)	
		Economic growth	Govt revenue generation	External borrowing	Reprioritisation		Health-earmarked sources		Technical efficiency gains		Expansion of HRH	Reduced undernourishment
					Health	HIV	Health risk-pooling mechanism	Alcohol tax	Reduced ART non-drug unit cost			
Low-Income Countries												
Ethiopia	48	4	39	40	18	0	3	0	31	364	182	53
Malawi	2	0.2	0	0	0	33	0	13	0	56	7	1
Mozambique	10	1	1	0	6	25	0	n.a.	5	106	23	10
Uganda	31	2	22	3	12	0	26	0	20	135	16	28
Tanzania	6	0.5	2	0	3	53	4	n.a.	4	192	27	6
Zimbabwe	30	1	0	0	n.a.	9	n.a.	n.a.	0	42	15	25
Lower-Middle-Income Countries												
Kenya	110	8	8	0	165	0	65	n.a.	66	493	111	85
Lesotho	141	9	0	0	5	0	0	n.a.	111	285	n.a.	n.a.
Nigeria	42	3	0	68	50	21	43	13	19	537	5	0
Swaziland	151	3	0	123	0	79	0	7	71	536	n.a.	n.a.
Zambia	17	1	3	7	0	69	0	n.a.	0	221	19	22
Upper-Middle-Income Countries												
Botswana	936	42	0	1,561	809	0	0	43	0	5,270	0	641
Namibia	823	41	0	389	68	0	0	n.a.	143	1,645	0	736
South Africa	340	10	0	0	54	222	0	16	100	797	0	0
Total LICs	19	1 (7%)	9 (46%)	4 (20%)	6 (31%)	21 (106%)	7 (37%)	2 (8%)	9 (47%)	148	32 (164%)	19 (97%)
Total LMICs	63	4 (7%)	2 (4%)	41 (64%)	63 (100%)	25 (40%)	37 (58%)	7 (12%)	34 (55%)	419	31 (49%)	23 (36%)
Total UMICs	387	12 (3%)	0 (0%)	90 (23%)	92 (24%)	204 (53%)	0 (0%)	17 (4%)	96 (25%)	1,115	0 (0%)	56 (14%)
OVERALL	159	6 (4%)	4 (2%)	44 (28%)	52 (33%)	84 (53%)	14 (9%)	9 (5%)	46 (29%)	433	21 (13%)	32 (20%)

Note: All monetary figures are in 2014US$. Maximum potential public spending per adult living with HIV is a cumulative value if all the sources are increased simultaneously, which is why it is more than the sum of each source.

Table S3.2. Technical Efficiency Gains Data and Sensitivity Analyses

Country	**Treatment and care spending per person receiving ARVs (2012 USD)**	Year of spending and no of people on ART data	**Adjusted spending per person retained** (2012 USD)	Non-drug cost per person retained (2012 USD)	**Ratio to GDP per capita** (2012)	**Potential savings as % of total treatment and care spending**	**Base case - Average annual efficiency savings from 2014-2018** (2014 USD)	**Sensitivity analyses**		
								Average annual efficiency savings with gradual gains (2014 USD)	**Average annual efficiency savings based on SSA best performer per income category** (2014 USD)	**Average annual efficiency savings based on linear relationship to per-capita GDP** (2014 USD)
LIC										
Ethiopia	500	2011	691	559	119%	63%	18,799,533	15,979,603	19,188,860	20,922,376
Malawi	162	2011	202	70	26%	0%	0	0	0	278,316
Mozambique	410	2011	554	422	65%	53%	7,267,865	6,177,685	7,517,512	7,949,714
Uganda	1,035	2008	1,478	1,346	235%	82%	34,919,679	29,681,727	35,177,644	35,971,769
Tanzania	615	2011	869	737	113%	70%	5,169,052	4,393,694	5,254,330	5,404,20
Zimbabwe	212	2012	269	137	**16%**	0%	0	0	1,266,901	0
LMIC										
Kenya	513	2012	703	571	57%	64%	92,154,809	78,331,588	92,154,809	99,403,821
Lesotho	965	2008	1,286	1,154	86%	80%	40,404,416	34,343,753	40,404,416	40,823,736
Nigeria	387	2012	527	395	24%	49%	61,196,796	52,017,276	61,196,796	58,587,579
Swaziland	462	2012	563	431	14%	48%	15,356,386	13,052,928	15,356,386	8,885,414
Zambia	208	2012	263	131	**9%**	0%	0	0	0	0
UMIC										
Botswana	1,312	2011	1,526	1,394	**15%**	0%	0	0	171,028,361	0
Namibia	1,396	2010	1,713	1,581	28%	18%	31,841,130	27,064,960	112,128,736	78,914,208
South Africa	1,713	2009	2,141	2,009	26%	31%	629,861,977	535,382,680	1,391,572,657	836,232,171
Total							**936,971,643**	**796,425,896**	**1,952,247,408**	**1,193,373,308**

4 Empirical approach to estimating Fiscal space using econometric analyses

4.1 Model specification

Cross-sectional econometric methods were used to estimate multivariate regression models investigating how much the different sources of fiscal space explain cross-country variance in public HIV spending. The specification of the main models was:

$$Y_j = \theta_i C_{ij} + \beta_i X_i + \alpha$$

where Y is public HIV spending per PLHIV for country i; C_{ij} is a vector of control variables c_i with θ_i vector of mean coefficients; X_i is a vector of explanatory variables x_i with β_i mean coefficient; and ε_j is an error term. We considered several explanatory variables that may influence each other, based on the fiscal space framework[11]. Table S4.1 summarises the control and explanatory variables, the indicators used and their expected relationship with the dependent variable.

Table S4.1. Summary of the independent variables in the regression models for Public HIV spending per PLHIV (PHIVSP)

Category	Indicator (Variable)	Source	Expected relationship
Control variables			
HIV disease burden	Adult HIV prevalence (PREV)	UNAIDS	+ greater need and prioritisation of HIV -economies of scale reduce expenditure per PLHIV
Governance	Control of corruption (CORR)	World Bank	+ greater prioritisation of HIV -more efficient spending
External financing	International HIV spending per PLHIV (INTHIVSP)	UNAIDS	+ crowding in -fungibility
Time	Year of HIV spending data (YR)	UNAIDS	+ technological change/ new technologies requiring larger investments
Regional characteristics	Regional dummies ($REG_{1...6}$)	UNAIDS	+/- depending on the region, access to generic drugs, type of epidemic/MARPs, political will
Conducive macroeconomic environment			
National income and price levels	GDP per capita (GDPpc)	IMF	+ HIV spending = normal good And tendency for citizens with growing income and education levels to demand more public spending on social services
Size and effectiveness of government	Government revenue, excluding grants (% of GDP) (REV/GDP)	IMF	+ more resources to allocate to meritorious investments
Borrowing			
Propensity to borrow	Gross debt to GDP ratio (DEBT/GDP)	IMF	+ if borrowing used for HIV or frees up other resource for HIV (MICs) - if borrowing is unsustainable & crowds out other government expenditure (more likely in LICs)

Category	Indicator (Variable)	Source	Expected relationship
Reprioritisation			
Prioritisation of health	Government health expenditure (% total government expenditure) (GHE/GE)	WHO	+ if HIV spending is largely channelled through government - if an increase in public health spending reflects an off-budget increase in donor HIV spending (fungibility)
Prioritisation of HIV	Public HIV spending (% of Government health expenditure) (PHIVSP/GHE)	UNAIDS/ WHO	+ if HIV spending is largely channelled through government
Earmarked HIV resources			
Risk-pooling or social health insurance mechanism	Out-of-pocket expenditure per capita (OOPpc)	WHO	- lack of public investment in health/HIV is being compensated by high OOP expenditures + OOP are financing public HIV services through user fees (problem = regressive)
Efficiency gains			
ART service efficiency	Non-drug cost per person on ART (ARTCOSTpp)	UNAIDS/ WHO	- given efficiency gains from economies of scale + if higher HIV spending to compensate for lower efficiency

The detailed linear form models that were estimated through regression were:

$$Ln\ PHIVSP = \beta_1 + \beta_2\ Ln\ PREV + \beta_3 CORR + \beta_4\ Ln\ INTHIVSP + \beta_k REG_n + \beta_{11} YR + \beta_{12}\ Ln\ GDPpc \quad (1)$$

$$Ln\ PHIVSP = \beta_1 + \beta_2\ Ln\ PREV + \beta_3 CORR + \beta_4\ Ln\ INTHIVSP + \beta_k REG_n + \beta_{11} YR + \beta_{12}\ Ln\ GDPpc + \beta_{13} Ln\ (REV/GDP) \quad (2)$$

$$Ln\ PHIVSP = \beta_1 + \beta_2\ Ln\ PREV + \beta_3 CORR + \beta_4\ Ln\ INTHIVSP + \beta_k REG_n + \beta_{11} YR + \beta_{12}\ Ln\ GDPpc + \beta_{13}\ Ln\ (DEBT/GDP) \quad (3)$$

$$Ln\ PHIVSP = \beta_1 + \beta_2\ Ln\ PREV + \beta_3 CORR + \beta_4\ Ln\ INTHIVSP + \beta_k REG_n + \beta_{11} YR + \beta_{12}\ Ln\ GDPpc + \beta_{13}\ Ln\ (GHE/GE) \quad (4)$$

$$Ln\ PHIVSP = \beta_1 + \beta_2\ Ln\ PREV + \beta_3 CORR + \beta_4\ Ln\ INTHIVSP + \beta_k REG_n + \beta_{11} YR + \beta_{12}\ Ln\ GDPpc + \beta_{13}\ Ln\ (OOPpc) \quad (5)$$

$$Ln\ PHIVSP = \beta_1 + \beta_2\ Ln\ PREV + \beta_3 CORR + \beta_4\ Ln\ INTHIVSP + \beta_k REG_n + \beta_{11} YR + \beta_{12}\ Ln\ GDPpc + \beta_{13}\ Ln\ (ARTCOSTpp) \quad (6)$$

$$Ln\ PHIVSP = \beta_1 + \beta_2\ Ln\ PREV + \beta_3 CORR + \beta_4\ Ln\ INTHIVSP + \beta_k REG_n + \beta_{11} YR + \beta_{12}\ Ln\ GDPpc + \beta_{13}\ Ln\ (PHIVSP/GHE) \quad (7)$$

Where k = 5, 6, ..., 10; n = 1, 2, ...6, and REG_1 = East & Southern Africa, REG_2 = Asia & Pacific region, REG_3 = Latin America region, REG_4 = Caribbean region; REG_5 = Easter Europe & Central Asia region; REG_6 = North Africa & Middle East region.

We explored various functional forms for the dependent and independent variables (linear, natural logarithms, and squared), and retained a natural logarithmic functional form for all expenditure data and proportion data, as they generally provided the best model fit and also allow us to interpret the model coefficients as elasticities.

Relevant interaction terms were also tested, such as the interacted effect of debt for middle-income countries, or the size of government and the quality of governance. Based on the higher Akaike information criterion (AIC) for these models, and in the interest of parsimony, we did not include them.

4.2 Model estimation

Since we were interested in the interdependence between fiscal space sources and the possibility that a change in one was likely to change another, we estimated independent models for each independent variable, using the same control variables. We estimated these models through Ordinary Least Squares (OLS), quantile regressions and neighbourhood fixed effects estimation methods, as presented below. More details on the methods, assumptions and results for each analytical approach are presented in sections 4.2.1, 4.2.2 and 4.2.3. All analyses were done in Stata version 12.0.

We used OLS regression to initially detect the indicators that drive costs assuming a linear relationship between the independent and dependent variables. An important characteristic of OLS is that it gives the mean prediction of the dependent variable and this can easily be affected by an extreme value or potential outliers. Quantile regression gives a more comprehensive picture of the relationship between the independent variables and the dependent variable, especially in the presence of extreme values. Quantile regression can be used to further examine and assess these relationships at specific percentiles (e.g. 25th, 50th, 75th, interquartile range). Neighbourhood fixed effects models were used to address the omitted variable bias that might be present in cross-sectional regression analyses. Detailed results for the quantile and neighbourhood effects models are presented in the following sections.

It is worth noting that results from OLS and quantile regressions were consistent in terms of statistical (in)significance for all predictors except for gross government debt as of % GDP and government health expenditure as % of government expenditure. These two predictors were statistically significant for specific quintiles. The neighbour and neighbourhood fixed effects models, on the other hand, found that the general government revenue (as % of GDP) and alcohol tax levels were significant predictors of public HIV spending, while health prioritisation was not. For all predictors, only GDP per person and public HIV spending as % of GHE were found to be statistically significant predictors of spending across different quintiles and in OLS.

4.2.1 **Ordinary Least Squares Method**

We ran regression diagnostics to verify that the data met the assumptions underlying OLS regression modelling. These assumptions, summarised elsewhere (http://www.ats.ucla.edu/stat/stata/webbooks/reg/chapter2/statareg2.htm), include: linearity, normality of residuals, homoscedasticity, well specified models, and the absence of multicollinearity.

We checked for the linearity assumption, i.e. the relationships between the predictors and the outcome variable should be linear, by producing plots of the standardised residuals against each of the predictor variables in the regression model. A nonlinear pattern would raise concerns regarding the linearity assumption. We also used the *acprplot* command in Stata, which produces an augmented component-plus-residual plot, for detecting non-linearity. We conclude that Model 7 has a smoothed line very close to the ordinary regression line, and the entire pattern seems quite uniform. For Models 1-6 the plots

appeared somewhat problematic either at the left or right end, which may be due to some potential influential points. But overall, they did not indicate any substantial concerns of non-linearity in the data.

To check for the normality of residuals (i.e. that the errors are normally distributed), we estimated kernel density and generated a kernel density and a normal density plot for each model (using the *kdensity* command with the *normal* option in Stata). We also generated standardised normal probability and quintile plots using the *pnorm* and *qnorm* commands in Stata. For all eight OLS models, the kernel density graphs were sensitive to non-normality near the tails. Moreover, the normal probability graphs were sensitive to non-normality in the middle range of the data and the quintile graph was sensitive to non-normality near the tails. However, this evidence was still not enough to seriously question the normality of our models.

To check for the homoscedasticity of residuals, we plotted the residuals versus fitted (predicted) values, using the *rvfplot* command in Stata with the *yline(0)* option. Signs of heteroscedasticity may be present if the residuals do not have an average value of zero and the spread is not the same in any thin vertical strip. In addition, we computed the White general test (using the *imest* command in Stata). Both commands test the null hypothesis that the variance of the residuals is homogenous. A small p-value ($p<0.05$) for the White test would indicate that variance is not homogeneous. We observed that in some of the models there may be a slight pattern in the plotted data, but the problem was too limited to raise concerns of heteroscedasticity. Given that the results from the White test yielded p-values in our models of more than 0.05, we failed to reject the null hypothesis of no constant variance, and therefore we accept that there are no heteroscedasticity issues.

We checked model specification using the results of two tests: a model specification link test for single-equation models (using the *linktest* command in Stata), and a regression equation specification error test for omitted variables, or the so-called Ramsey RESET test (using the *ovtest* command in Stata). For the former, none of the the estimated prediction squared had any explanatory power, suggesting that our models appear to be correctly specified. Regarding the latter, the p-values were not small enough ($p<0.05$) to reject the null hypothesis, which states that the model has no omitted variables, hence there is no indication that our models suffer from endogeneity.

To diagnose whether our models suffer from multicollinearity, we first inspected the correlation matrix (Table S6) for high pairwise correlations among regressors. Only HIV prevalence and HIV prioritisation in the health budget had a correlation factor above 0.7 (0.73). Given the high correlation between HIV prevalence and HIV prioritisation in the health budget (0.73), we also re-ran model 7 without HIV prevalence. The signs and significance levels of all coefficients remained the same, with the exception of the regional dummies that unsurprisingly absorbed some of the HIV prevalence data.

We further assessed multicollinearity by using the variance inflation factor (VIF), which is implemented with the *vif* post estimation command in Stata. In all our models, the VIF was less than 10, which is considered acceptable, and implies that it is reasonable to assume that we do not have issues of multicollinearity.

Table S4.2. Correlation Matrix

	Public HIV spending per PLHIV	HIV prevalence	Control of corruption	International HIV spending PLHIV	Year of spending data	GDP per person	Govt revenue, excl. grants as % GDP	Gross central govt debt as % GDP	Govt Health Expenditure as % Govt Expenditure	Out-of-pocket expenditure per person	Non-drug cost per person on ART	Public HIV spending as % of GHE
Public HIV spending per PLHIV	1.00											
HIV prevalence	-0.30	1.00										
Control of corruption	0.43	0.02	1.00									
International HIV spending per person	-0.03	-0.17	0.02	1.00								
Year of spending data	0.14	-0.19	-0.07	0.06	1.00							
GDP per person	0.78	-0.19	0.48	-0.31	0.02	1.00						
Government revenue, excl. grants as % GDP	0.44	0.13	0.07	-0.11	-0.05	0.23	1.00					
Gross central government debt as % GDP	-0.18	-0.20	0.18	0.02	0.00	0.02	-0.18	1.00				
Government Health Expenditure as % Government Expenditure	0.25	0.13	0.36	0.01	-0.06	0.11	0.01	-0.13	1.00			
Out-of-pocket expenditure per person	0.64	-0.38	0.21	-0.24	0.13	0.74	0.24	0.07	0.11	1.00		
Non-drug cost per person on ART	0.57	-0.41	0.28	0.05	-0.13	0.54	0.14	-0.03	0.04	0.44	1.00	
Public HIV spending as % of GHE	0.20	0.73	0.02	-0.06	-0.03	-0.13	0.07	-0.18	-0.01	-0.17	-0.20	1.00

4.2.2 **Quantile regressions**

Quantile regression is used to provide a more comprehensive picture of the effect of the predictors on the dependent variable by modelling the relationship between a set of independent variables and specific percentiles (or quantiles) of the dependent variable[12]. For example, a median regression specifies the changes in the median value of the dependent variable as a function of the predictors. The effects of the independent variables may vary over quantiles of the conditional distribution, which is an important advantage of quantile regression over mean regression. The sensitivity of standard OLS regression to outliers was another reason to additionally estimate and analyse quantile regressions.

We used the *qreg* and *iqreg* commands in Stata to fit the regression models. The qreg command estimates quantile regression and reports standard errors and t-statistics that are asymptotically valid under heteroskedasticity and misspecification. We performed median, 25th and the 75th quintiles as well as interquantile regression. The command *iqreg* reports coefficients that are the difference in coefficients of two *qreg* models and standard errors obtained through bootstrapping.

In the median regression the constant is the median of the sample while in the 25th or 75th quantile regression the constant is the 25th or 75th percentile for the sample, respectively. For example, the interpretation of the median regression of public HIV spending per PLHIV on GDP per capita in model 1 specifies the changes in the median public HIV spending per PLHIV as a function of the predictors. The effect of all predictors in the model on public HIV spending per PLHIV can be compared to its effect on other quantiles of public HIV spending per PLHIV. As we observed in the normal quantile plots vs residuals in OLS, there was a different behaviour of the observations close to the tails. The quantile regressions allowed us to look into more detail at the behaviours of the models at the tails.

Table S7. Dependent variable Logged Public HIV Spending PLHIV (50th Quintile – Median)

	1	2	3	4	5	6	7
Control variables							
HIV prevalence	-0.311**	-0.342**	-0.280	-0.218*	-0.203**	-0.294*	-0.797***
	(0.147)	(0.166)	(0.202)	(0.166)	(0.155)	(0.175)	(0.107)
Control of corruption	0.387**	0.379	0.346	0.232	0.271*	0.439*	0.330**
	(0.299)	(0.321)	(0.371)	(0.356)	(0.310)	(0.351)	(0.181)
International HIV spending per PLHIV	0.165***	0.166**	0.150	0.157**	0.187***	0.178**	0.048
	(0.112)	(0.120)	(0.142)	(0.125)	(0.115)	(0.133)	(0.068)
Year of spending data	0.090	0.088	0.072	0.126	0.123	0.020	-0.040
	(0.104)	(0.113)	(0.135)	(0.117)	(0.109)	(0.118)	(0.063)
Reference: West & Central Africa							
East & Southern Africa	1.050**	1.057**	1.046*	0.868**	1.007**	0.831*	0.178
	(0.424)	(0.458)	(0.589)	(0.473)	(0.452)	(0.470)	(0.257)
Asia & Pacific region	0.027	-0.083	0.076	0.315	0.201	-0.083	0.060
	(0.482)	(0.524)	(0.642)	(0.535)	(0.504)	(0.546)	(0.291)
Latin America region	1.087***	1.040**	1.127*	1.087***	1.322***	1.160**	0.728***
	(0.512)	(0.551)	(0.649)	(0.598)	(0.532)	(0.606)	(0.315)
Caribbean region	-0.484	-0.392	-0.374	-0.500	-0.498	-0.493	0.167
	(0.649)	(0.699)	(0.826)	(0.720)	(0.532)	(0.710)	(0.393)
Easter Europe & Central Asia region	0.371	0.167	0.421	0.876	0.485	0.376	0.584
	(0.580)	(0.646)	(0.782)	(0.644)	(0.601)	(0.661)	(0.352)
North Africa & Middle East region	-0.927	-1.064	-0.036	-0.445	-0.788	-0.157	0.539
	(0.645)	(0.706)	(0.867)	(0.718)	(0.672)	(0.778)	(0.396)
Explanatory variables							
GDP per person	1.102***	1.073***	1.077***	1.082***	1.022***	1.145***	0.976***
	(0.183)	(0.215)	(0.234)	(0.205)	(0.262)	(0.211)	(0.111)
Government revenue, excl. grants as % GDP		0.242					
		(0.452)					
Gross government debt as % GDP			-0.065				
			(0.301)				
Government Health Expenditure as % Government Expenditure				0.419***			
				(0.337)			
Out-of-pocket expenditure per person					0.035		
					(0.220)		
Alcohol Excise Tax							
Non-drug cost per person on ART						-0.024	
						(0.166)	
Public HIV spending as % of GHE							0.783***
							(0.074)
Constant	-189.623	-183.799	-151.828	-259.692	-254.350	-48.515	75.559
	(210.000)	(227.773)	(270.839)	(235.205)	(219.284)	(237.491)	(127.702)
Observations	92	92	87	91	90	86	92
Pseudo R^2	0.53	0.53	0.55	0.54	0.53	0.57	0.74
df_m	11	12	12	12	12	12	12
df_r	80	79	74	79	78	73	79

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table S8. Dependent variable Logged Public HIV Spending PLHIV (25th Quintile)

	1	2	3	4	5	6	7
Control variables							
HIV prevalence	-0.361*	-0.330	-0.308	-0.274	-0.363*	-0.349**	-0.761***
	(0.233)	(0.248)	(0.203)	(0.230)	(0.233)	(0.174)	(0.099)
Control of corruption	0.319	0.249	0.005	0.248	0.316	0.366	0.364***
	(0.474)	(0.481)	(0.544)	(0.492)	(0.467)	(0.350)	(0.166)
International HIV spending per PLHIV	0.127	0.179	0.169	0.146	0.127	0.111	0.027
	(0.177)	(0.180)	(0.180)	(0.172)	(0.173)	(0.132)	(0.063)
Year of spending data	0.032	0.018	0.045	0.062	0.030	0.027	-0.032
	(0.166)	(0.170)	(0.161)	(0.162)	(0.165)	(0.118)	(0.058)
Reference: West & Central Africa							
East & Southern Africa	-0.263	-0.084	0.157	-0.202	-0.262	-0.263	0.013
	(0.672)	(0.686)	(0.681)	(0.655)	(0.682)	(0.468)	(0.237)
Asia & Pacific region	-0.284	-0.090	-0.236	0.122	-0.293	-0.291	-0.029
	(0.765)	(0.783)	(0.847)	(0.740)	(0.761)	(0.544)	(0.269)
Latin America region	0.883	0.786	1.024	0.964	0.880	0.768*	0.793***
	(0.813)	(0.824)	(0.842)	(0.827)	(0.803)	(0.604)	(0.290)
Caribbean region	-0.515	-0.639	-0.478	-0.483	-0.518	-0.538*	0.387
	(1.030)	(1.045)	(1.127)	(0.996)	(1.030)	(0.707)	(0.362)
Easter Europe & Central Asia region	0.184	0.031	0.171	0.226	0.180	0.151	0.410
	(0.919)	(0.966)	(0.867)	(0.892)	(0.906)	(0.658)	(0.324)
North Africa & Middle East region	-2.047**	-1.855*	-0.858	-1.866*	-2.046**	-0.222	0.128
	(1.023)	(1.056)	(0.996)	(0.994)	(1.013)	(0.775)	(0.365)
Explanatory variables							
GDP per person	1.207***	1.207***	1.271***	1.205***	1.211***	1.186***	0.904***
	(0.290)	(0.321)	(0.333)	(0.283)	(0.395)	(0.210)	(0.102)
Government revenue, excl. grants as % GDP		0.312					
		(0.677)					
Gross government debt as % GDP			-0.022				
			(0.358)				
Government Health Expenditure as % Government Expenditure				0.189			
				(0.466)			
Out-of-pocket expenditure per person					-0.002		
					(0.332)		
Alcohol Excise Tax							
Non-drug cost per person on ART						0.045	
						(0.165)	
Public HIV spending as % of GHE							0.851***
							(0.068)
Constant	-72.032	-44.667	-98.305	-132.517	-68.406	-62.538	60.002
	(333.171)	(340.697)	(323.869)	(325.596)	(330.818)	(236.495)	(117.650)
Observations	92	92	87	91	90	86	92
Pseudo R^2	0.52	0.52	0.51	0.52	0.52	0.59	0.76
df_m	11	12	12	12	12	12	12
df_r	80	79	74	79	77	73	79

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table S9. Dependent variable Logged Public HIV Spending PLHIV (75th Quintile)

	1	2	3	4	5	6	7
Control variables							
HIV prevalence	-0.181* (0.138)	-0.241* (0.151)	-0.194 (0.235)	-0.156* (0.110)	-0.160 (0.138)	-0.191 (0.134)	-0.849*** (0.127)
Control of corruption	0.751*** (0.281)	0.628** (0.292)	0.561 (0.463)	0.439** (0.236)	0.426 (0.277)	0.757*** (0.269)	0.155 (0.215)
International HIV spending per PLHIV	0.110* (0.105)	0.138** (0.109)	0.133 (0.186)	0.116* (0.083)	0.167 (0.103)	0.092 (0.101)	0.081 (0.082)
Year of spending data	0.073 (0.098)	0.092 (0.103)	0.121 (0.180)	0.006 (0.078)	0.111 (0.098)	-0.054 (0.090)	-0.150* (0.076)
Reference: West & Central Africa							
East & Southern Africa	0.203 (0.399)	0.408 (0.416)	0.310 (0.633)	0.277 (0.314)	0.422 (0.404)	-0.028 (0.360)	0.009 (0.306)
Asia & Pacific region	0.120 (0.454)	0.103 (0.476)	-0.213 (0.729)	0.062 (0.355)	0.021 (0.451)	0.049 (0.418)	0.242 (0.347)
Latin America region	1.210*** (0.482)	1.343*** (0.501)	1.035 (0.826)	1.155*** (0.396)	1.506*** (0.476)	1.190** (0.463)	0.525 (0.375)
Caribbean region	-0.150 (0.611)	-0.017 (0.635)	-0.353 (1.031)	-0.313 (0.477)	-0.185 (0.611)	-0.172 (0.543)	-0.198 (0.468)
Easter Europe & Central Asia region	0.854 (0.545)	0.646 (0.587)	0.695 (0.893)	1.013*** (0.427)	0.898* (0.537)	0.641(0.06)	0.359 (0.419)
North Africa & Middle East region	-0.466 (0.607)	-0.530 (0.642)	-0.464 (0.963)	-0.014 (0.476)	-0.186 (0.601)	-0.447 (0.595)	0.239 (0.472)
Explanatory variables							
GDP per person	0.754*** (0.172)	0.652*** (0.195)	0.848*** (0.264)	0.841*** (0.136)	0.941*** (0.234)	0.631*** (0.161)	0.945*** (0.132)
Government revenue, excl. grants as % GDP		0.486 (0.411)					
Gross government debt as % GDP			-0.074 (0.436)				
Government Health Expenditure as % Government Expenditure				0.675*** (0.223)			
Out-of-pocket expenditure per person					-0.144 (0.197)		
Alcohol Excise Tax							
Non-drug cost per person on ART						0.146 (0.127)	
Public HIV spending as % of GHE							0.812*** (0.088)
Constant	-152.102 (197.659)	-188.038 (206.948)	-247.998 (361.575)	-14.798 (155.950)	-227.866 (196.233)	103.585 (181.644)	297.993** (152.160)
Observations	92	92	87	91	90	86	92
Pseudo R^2	0.53	0.53	0.54	0.58	0.53	0.57	0.72
df_m	11	12	12	12	12	12	12
df_r	80	79	74	78	77	73	79

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table S10. Dependent variable Logged Public HIV Spending PLHIV (25^{th}-75^{th})

	1	2	3	4	5	6	7
Control variables							
HIV prevalence	0.180	0.089	0.014	0.118	0.203	0.157	-0.088
	(0.233)	(0.386)	(0.273)	(0.220)	(0.208)	(0.226)	(0.179)
Control of corruption	0.432	0.379	0.556	0.192	0.110	0.391	-0.209
	(0.579)	(0.538)	(0.530)	(0.538)	(0.601)	(0.380)	(0.230)
International HIV spending per person	-0.017	-0.041	-0.036	-0.031	0.040	-0.019	0.054
	(0.176)	(0.197)	(0.216)	(0.191)	(0.230)	(0.119)	(0.099)
Year of spending data	0.041	0.073	0.076	-0.056	0.081	-0.081	-0.118
	(0.171)	(0.178)	(0.131)	(0.148)	(0.129)	(0.136)	(0.085)
Reference: West & Central Africa							
East & Southern Africa	0.466	0.492	0.153	0.479	0.684	0.235	-0.004
	(0.661)	(0.953)	(0.508)	(0.815)	(0.910)	(0.480)	(0.345)
Asia & Pacific region	0.404	0.192	0.023	-0.060	0.314	0.340	0.271
	(0.674)	(0.727)	(0.938)	(0.994)	(0.771)	(0.651)	(0.509)
Latin America region	0.328	0.557	0.011	0.191	0.626	0.422	-0.267
	(0.598)	(0.713)	(0.885)	(0.592)	(0.590)	(0.645)	(0.442)
Caribbean region	0.365	0.622	0.125	0.170	0.332	0.366	-0.584
	(0.751)	(0.694)	(0.667)	(0.607)	(0.775)	(0.516)	(0.389)
Easter Europe & Central Asia region	0.670	0.615	0.525	0.787	0.717	0.490	-0.051
	(0.692)	(0.946)	(0.728)	(0.897)	(0.697)	(0.744)	(0.492)
North Africa & Middle East region	1.581	1.325	0.395	1.852	1.860	-0.225	0.112
	(1.093)	(1.681)	(1.074)	(1.346)	(1.423)	(1.236)	(0.523)
Explanatory variables							
GDP per person	-0.453*	-0.555	-0.423	-0.363	-0.270	-0.555***	0.041
	(0.235)	(0.335)	(0.298)	(0.238)	(0.304)	(0.192)	(0.145)
Government revenue, excl. grants as % GDP		0.173					
		(0.820)					
Gross government debt as % GDP			-0.052				
			(0.390)				
Government Health Expenditure as % Government Expenditure				0.486			
				(0.449)			
Out-of-pocket expenditure per person					-0.142		
					(0.247)		
Alcohol Excise Tax							
Non-drug cost per person on ART						0.100	
						(0.235)	
Public HIV spending as % of GHE							-0.039
							(0.093)
Constant	-80.069	-143.371	-149.694	117.719	-159.459	166.123	237.991
	(344.186)	(358.550)	(264.357)	(296.967)	(259.907)	(274.703)	(170.436)
Observations	92	92	87	91	90	86	92
0.75 Pseudo R^2	0.53	0.53	0.54	0.57	0.53	0.57	0.71
0.25 Pseudo R^2	0.52	0.52	0.51	0.52	0.52	0.59	0.76
df_r	80	79	74	78	77	73	79

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.2.3 **Neighbour and Neighbourhood Fixed Effects**

Cross-sectional regressions are vulnerable to omitted variable bias as they seek to compare countries that are different in many dimensions. In order to reduce this risk, we undertook a matching exercise between neighbouring countries[13]. The underlying assumption of the approach is that neighbouring countries are likely to be more similar. Therefore, by comparing neighbouring countries, the matching strategy aims at controlling for unobserved characteristics that are similar between neighbouring countries.

We used three matching strategies. First, we reshaped our dataset to identify each pair of neighbouring country by a dummy. We then included these dummies as "geographical" fixed effects in the regressions. As countries may have several neighbours and be the neighbours of several countries, some lines will be duplicated in this new dataset. Standard errors are therefore clustered at multiple levels[13-14].

Instead of considering all pairs of neighbouring countries, the second approach proposes to randomly match each country with one of its neighbour. To avoid selection bias, the random matching procedure is repeated 200 times, and the average of estimated coefficients and standard errors are reported. Standard errors are clustered at the country level to account for the fact that the same country can appear in multiple pairs.

In the last method, we reshape the dataset to identify each neighbourhood of countries by a dummy. The neighbourhood of a country includes the country plus all its neighbours. Standard errors are clustered at multiple levels to account for the fact that countries may have multiple neighbours and may be the neighbour of multiple countries.

Table S11. Neighbourhood, pair and random fixed effects models for each explanatory variable

	1	2	3
Control variables			
HIV prevalence	-0.363** (0.162)	-0.391** (0.176)	-0.334** (0.148)
Control of corruption	0.505** (0.204)	0.412* (0.217)	0.473** (0.217)
International HIV spending per PLHIV	0.0928 (0.159)	0.138 (0.141)	0.154 (0.128)
Year of spending data	-0.0266 (0.0817)	-0.0156 (0.0737)	-0.00447 (0.0832)
Explanatory variables			
GDP per person	**1.168*** **(0.174)**	**1.190*** **(0.170)**	**1.246*** **(0.150)**
Observations	542	162	352
Fixed Effects	Pair	Random Pair	Neighbourhood

	1	2	3
Control variables			
HIV prevalence	-0.411** (0.163)	-0.464** (0.180)	-0.378** (0.147)
Control of corruption	0.558** (0.230)	0.426* (0.231)	0.549** (0.238)
International HIV spending per PLHIV	0.0731 (0.146)	0.126 (0.127)	0.123 (0.122)

Year of spending data	-0.00653 (0.0876)	-0.00415 (0.0758)	0.0134 (0.0886)
Explanatory variables			
GDP per person	1.039*** (0.191)	1.086*** (0.169)	1.090*** (0.173)
Government revenue, excl. grants as % GDP	**0.850** **(0.421)**	**0.845** **(0.355)**	**0.825** **(0.395)**
Observations	542	162	352
Fixed Effects	Pair	Random Pair	Neighbourhood

	1	2	3
Control variables			
HIV prevalence	-0.367*** (0.136)	-0.353** (0.159)	-0.359*** (0.135)
Control of corruption	0.431** (0.202)	0.412* (0.211)	0.389* (0.225)
International HIV spending per PLHIV	0.104 (0.135)	0.0653 (0.0998)	0.149 (0.123)
Year of spending data	0.0106 (0.0818)	0.0267 (0.0698)	0.0191 (0.0868)
Explanatory variables			
GDP per person	1.108*** (0.161)	1.063*** (0.153)	1.189*** (0.151)
Gross government debt as % GDP	**-0.0758** **(0.194)**	**-0.00471** **(0.162)**	**-0.145** **(0.182)**
Observations	496	152	324
Fixed Effects	Pair	Random Pair	Neighbourhood

	1	2	3
Control variables			
HIV prevalence	-0.304* (0.165)	-0.306* (0.174)	-0.284* (0.157)
Control of corruption	0.429** (0.216)	0.332 (0.243)	0.377* (0.225)
International HIV spending per PLHIV	0.0672 (0.146)	0.0862 (0.121)	0.137 (0.122)
Year of spending data	-0.0179 (0.0800)	-0.00540 (0.0728)	0.00585 (0.0859)
Explanatory variables			
GDP per person	1.141*** (0.154)	1.122*** (0.155)	1.236*** (0.142)
Government Health Expenditure as % Government Expenditure	**0.199** **(0.206)**	**0.284** **(0.222)**	**0.229** **(0.197)**
Observations	538	160	349
Fixed Effects	Pair	Random Pair	Neighbourhood

	1	2	3
Control variables			
HIV prevalence	-0.329** (0.158)	-0.361** (0.173)	-0.328** (0.147)
Control of corruption	0.554*** (0.186)	0.455* (0.233)	0.505** (0.210)
International HIV spending per PLHIV	0.0587 (0.140)	0.0782 (0.120)	0.130 (0.122)
Year of spending data	-0.0285 (0.0838)	-0.0145 (0.0746)	-0.00724 (0.0859)
Explanatory variables			
GDP per person	1.269***	1.231***	1.304***

	(0.248)	(0.250)	(0.220)
Out-of-pocket expenditure per person	**-0.157**	**-0.107**	**-0.107**
	(0.165)	**(0.159)**	**(0.168)**
Observations	522	158	340
Fixed Effects	Pair	Random Pair	Neighbourhood

	1	2	3
Control variables			
HIV prevalence	-0.286*	-0.320*	-0.270*
	(0.168)	(0.173)	(0.151)
Control of corruption	0.531***	0.472**	0.500**
	(0.204)	(0.206)	(0.207)
International HIV spending per PLHIV	0.0612	0.0936	0.107
	(0.151)	(0.118)	(0.116)
Year of spending data	-0.0742	-0.0544	-0.0482
	(0.0624)	(0.0644)	(0.0660)
Explanatory variables			
GDP per person	1.021***	1.075***	1.062***
	(0.138)	(0.153)	(0.131)
Non-drug cost per person on ART	**0.182**	**0.124**	**0.233****
	(0.127)	**(0.108)**	**(0.116)**
Observations	480	152	316
Fixed Effects	Pair	Random Pair	Neighbourhood

	1	2	3
Control variables			
HIV prevalence	-1.006***	-1.028***	-1.022***
	(0.110)	(0.124)	(0.0781)
Control of corruption	0.383***	0.337**	0.341***
	(0.136)	(0.144)	(0.111)
International HIV spending per PLHIV	0.0503	0.0842	0.0725
	(0.0879)	(0.0989)	(0.0732)
Year of spending data	-0.0424	-0.0482	-0.0372
	(0.0492)	(0.0538)	(0.0412)
Explanatory variables			
GDP per person	1.056***	1.076***	1.047***
	(0.142)	(0.121)	(0.100)
Public HIV spending as % of Government Health Expenditure	**0.715***	**0.688***	**0.758***
	(0.111)	**(0.117)**	**(0.0767)**
Observations	542	162	352
Fixed Effects	Pair	Random Pair	Neighbourhood

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5 HIV prioritisation model

To explore what is driving HIV prioritisation, as the final step in the government resource allocation process, we estimate a model for Public HIV spending as a % of Government Health Expenditure. We log transformed the dependent and the independent variables (except the dummies) and estimated the model with OLS. We included the *robust* option to obtain robust standard errors, in case we misspecified the distribution function.

Table S12. Dependent variable Logged Proportion of Public HIV Spending in Government Health Expenditure

Control variables	Coefficient	SE
HIV prevalence	0.671***	(0.114)
Control of corruption	0.423*	(0.231)
International HIV spending per person living with HIV	0.141*	(0.073)
Year of spending data	0.067	(0.089)
Reference: West & Central Africa		
East & Southern Africa	0.204	(0.397)
Asia & Pacific region	-0.339	(0.430)
Latin America region	0.881*	(0.448)
Caribbean region	-0.401	(0.475)
Easter Europe & Central Asia region	0.139	(0.520)
North Africa & Middle East region	0.068	(0.458)
Explanatory variables		
GDP per person	0.138	(0.220)
Government revenue, excl. grants as % GDP	-0.506	(0.315)
Gross government debt as % GDP	-0.330*	(0.168)
Government Health Expenditure as % Government Expenditure	-0.737***	(0.243)
Out-of-pocket expenditure per person	-0.102	(0.202)
Non-drug cost per person on ART	0.079	(0.130)
Constant	-143.063	(178.935)
Observations	80	
R^2	0.607	
AIC	219	
BIC	260	
F	11.986	
df_m	16	
df_r	63	
White test (p-value)	80 (0.447)	
Ramsey RESET test(p-value)	1.43 (0.244)	
VIF	2.70	
Linktest (_hatsq p value)	0.566	

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

6 PMTCT screening model

Our theoretical model is a standard economic Cobb-Douglas production function for the technological relationship between HIV programme output and factor inputs[15], namely:

$$Y = A\,L^{\beta}\,K^{\alpha}$$

Where Y is total HIV service outputs (production), L is labour inputs (health personnel), K is capital input (HIV spending), A is total factor productivity, and α and β are the output elasticities of capital and labour.

This area of our exploration was particularly constrained by data availability, and our measures were limited. We chose to analyse the production of Prevent Mother-to-Child Transmission (PMTCT) screening services, using selected HIV-specific and non-HIV inputs. These choices were largely driven by data availability, as well as the health system constraints framework developed by Hanson et al[16]. The latter describes the constraints of scaling up priority health interventions and distinguishes between five levels of constraints, starting with the community and household level (i.e. the demand side), followed by a health service delivery level and a health sector governance level of constraints (i.e. the supply side); and finally broader public sector and environmental levels of constraints. Ranson et al use this framework to develop a typology of countries, using empirical data[17]. We build on the indicators they selected to include for each level of constraint, as well as previous work on health worker density and health service coverage[18], to construct our model below.

With an increasing reliance on provider-initiated HIV testing and counselling and the importance of antenatal care services as an entry point into ART and PMTCT services, it is clear that the demand and therefore scale up of core HIV services depends on the capacity of other health services in the health system. There is evidence that the availability of qualified medical personnel is particularly critical for effective maternal health services and outcomes[19-20]. We therefore selected a measure of health worker density as a non-HIV policy lever that could enable increased HIV (PMTCT) programme efficiency, among others. The other two non-HIV areas of investment we explored were female education and food insecurity, given their expected and identified role in the uptake of maternal health and PMTCT services[21].

In our model (see Table S13), the dependent variable was PMTCT screening coverage, namely the proportion of pregnant women tested for HIV (from the UNAIDS Aidsinfo database). The explanatory variables of interest were financial HIV inputs (total HIV spending per PLHIV) and human resource inputs (nurse density). We also considered demand-side inputs or constraints, namely female education (adult female literacy)[16, 18] and food insecurity (proportion of people malnourished in the total population). Additionally, we controlled for GDP per capita[22], disease burden (adult HIV prevalence), and environmental factors that may affect accessibility and efficiency, namely urbanisation rate and governance (control of corruption)[16-17]. All independent variables were transformed into natural logarithms in the estimated regression equation, in line with the exponential Cobb-Douglas function.

Since the dependent variable is bounded (0-100 %), we used a generalised linear model with logit link function[23] and the binomial family. We also tried the censored Tobit model to test the robustness of the linear approximation.

The model suggests that countries with higher HIV prevalence, higher HIV spending, higher nurse density and lower undernourishment, achieved higher PMTCT screening coverage. While female education and urbanisation rates had the expected signs, they were not statistically significant (at $p<0.10$). As has been found in similar research on health worker density and health service coverage, GDP per capita did not enter significantly in the model[18]. However, surprisingly, the same underlying relationships were not found for ART coverage (analyses not shown), which has been scaled up at a remarkable pace, in spite of human resource shortages[24].

Besides the specification issues mentioned above, one major limitation of this model is the use of total HIV spending instead of PMTCT spending, due to data availability. The latter would have been a more accurate reflection of the production function. However, if we assume a relatively constant proportion of PMTCT spending in total spending, the modelled relationship would still hold.

Table S13. Dependent variable PMTCT screening coverage among pregnant women (GLM)

Variables	Coefficient (SE)
Log HIV prevalence	0.796*** (0.139)
Log GDP per person	-0.411* (0.247)
Log Total HIV spending per PLHIV	0.752*** (0.212)
Log Control of corruption	1.964 (2.021)
Log Nurses & Midwives density	0.535*** (0.204)
Log Urbanisation	0.314 (0.431)
Log Adult Female Literacy Rate	0.548 (0.566)
Log Proportion undernourished	-0.451** (0.224)
Constant	-1.729 (3.802)
Observations	60
AIC	67
BIC	85
df_m	8

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In microeconomic theory, production functions are characterised by a combination of complementary inputs that are used to produce a final good or service. In terms of PMTCT screening, we could think of HIV testing kits (captured by HIV spending) and nurses being complementary inputs required to provide screening services to pregnant women[18]. Depending on the malleability of capital and adaptability of

labour in the short-term, there is likely to be some degree of substitution between such imperfect complements[25]. Based on this, we considered that increasing one of the HIV or non-HIV inputs in the production function could increase HIV service production, as suggested by the model.

Thus, using the above model, we estimated how much more PMTCT screening coverage could be achieved if countries were to reach the WHO minimum norm of having 2.3 health workers per 1000 population[26], and then estimated how much more a country would have had to spend from the HIV budget to achieve that same increase – as a measure of potential HIV budget saving (see Table S14). In economic terms, we calculated the rate of technical substitution between labour and financial inputs, to get to a monetary valuation of reaching the norm of health worker density, for the HIV budget constraint[27]. This monetary value is equivalent to the extra HIV spending that would be required to reach the same level of PMTCT screening coverage (a proxy of HIV service outputs), as would have been achieved from increasing the number of health workers to the norm (through another budget). We then apply that percentage increase in total spending to the public HIV spending figure.

Similarly, we estimate how a reduction in undernourishment to the MDG target of 11.7% (half of 1990 level in developing countries of 23.4%)[28], could produce HIV pay-offs in terms of increased PMTCT screening coverage. We then estimate how much extra HIV spending would have been required to get the same increase (see Table S15).

In mathematical terms, the logarithmic transformation of the production function above provides a log-linear form that can be used within a regression framework. A more general form of the function allows for the estimation of the exponentiated coefficient values and hypothesis testing:

$$\ln Y = \ln A + \beta \times \ln L + \alpha \times \ln K$$

The derivative of this log-linear form can be taken while taking into account changes of Y, A, L and K over time. This derivative can be interpreted as the percentage change in Y:

$$dY / Y = dA / A + \beta \times dL / L + \alpha \times dK / K$$

or

$$\Delta Y = \Delta A + \beta \times \Delta L + \alpha \times \Delta K$$

The above formula can be used to illustrate the proportion of real output growth in relation to increases in L or K inputs and total factor productivity.

The linear form model that was estimated through GLM regression was:

$$\text{Ln PMTCT\_SCREENCOV} = \beta_1 + \beta_2 \text{ Ln PREV} + \beta 3 \text{ GDPpc} + \beta_4 \text{ Ln TOTHIVSP} + \beta_5 \text{ Ln CORR} + \beta_6 \text{ Ln NURS} + \beta_7 \text{ Ln URBAN} + \beta_8 \text{ Ln LITERATE} + \beta_9 \text{ Ln UNDERNOUR}$$

The formula used to calculate the predicted values was:

Predicted PMTCT SCREENCOV = $1/(1+ EXP(-(\beta_2$ Ln PREV + $\beta 3 GDP_{pp}$ + β_4 Ln TOTHIVSP + β_5 Ln CORR + β_6 Ln NURS + β_7 Ln URBAN + β_8 Ln LITTERATE + β_9 Ln UNDERNOUR)))

Table S14. Potential returns from expanding health worker density for PMTCT programme

Variable	Nurse density (target= 2.3 per 1000 minus physician density)	Predicted PMTCT screening coverage	New calculated PMTCT screening coverage with target	Calculated Total HIV spending per PLHIV (2012USD)	Original Total HIV spending per PLHIV (2012USD)	Percentage increase in spending
Botswana	**2.8**	-	-	-	-	0%
Ethiopia	0.25	23%	50%	1,445	303	380%
Kenya	0.79	78%	85%	965	479	100%
Lesotho	0.6	n.a.	n.a.	n.a.	n.a.	n.a.
Malawi	0.34	66%	84%	406	106	290%
Mozambique	0.4	63%	81%	569	170	240%
Namibia	**2.8**	-	-	-	-	0%
Nigeria	1.6	65%	67%	187	166	10%
South Africa	**4.9**	-	-	-	-	0%
Swaziland	1.6	n.a.	n.a.	n.a.	n.a.	n.a.
Uganda	1.3	76%	81%	358	239	50%
Tanzania	0.2	45%	75%	1,114	196	470%
Zambia	0.78	77%	85%	531	252	110%
Zimbabwe	1.25	86%	90%	343	227	50%

Table S15. Potential returns from reduced undernourishment for PMTCT programme

Variable	Undernourished in total population (target= 11.7%)	Predicted PMTCT screening coverage	New calculated PMTCT screening coverage with target	Calculated Total HIV spending per PLHIV (2012USD)	Original Total HIV spending per PLHIV (2012USD)	Percentage increase in spending
Botswana	27.9%	98%	98%	2,031	1,205	68%
Ethiopia	40.2%	23%	35%	635	303	110%
Kenya	30.4%	78%	84%	850	479	77%
Lesotho	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Malawi	23.1%	66%	73%	159	106	50%
Mozambique	39.2%	63%	75%	350	170	107%
Namibia	33.9%	96%	97%	2,496	1,318	89%
Nigeria	8.5%	-	-	-	-	0%
South Africa	5.0%	-	-	-	-	0%
Swaziland	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Uganda	34.6%	76%	84%	457	239	92%
Tanzania	38.8%	45%	59%	402	196	105%
Zambia	47.4%	77%	86%	584	252	132%
Zimbabwe	32.8%	86%	91%	421	227	86%

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Appendix 3

1. Literature review of effectiveness studies

Table S1. Overview of studies that assessed the effectiveness of food assistance for people on ART in low and middle-income countries on measures of treatment adherence and attrition

Study	Country & Study population	Study design & Food basket	Outcome indicators	Findings
Cantrell et al 2008	Zambia PLHIV on ART recruited based on food insecurity status	Partly retrospective study, comparing data from PLHIV on ART at clinics with food assistance to PLHIV at clinics without food assistance (145 vs 147 PLHIV) Analysis used Propensity Score Matching (PSM) **Food basket:** 25 kg maize, 6 kg corn soya blend (CSB), 4.5 kg peas, 1.8 L vegetable oil per month *(household ration)*	Adherence to ART, using pharmacy refill records Weight gain CD4 count	Food assistance recipients had higher ART adherence compared to non-recipients at 12 months after ART initiation: 98.3% vs 88.8 % (p<0.01) Greater improvement in adherence among participants on ART<230 days and with BMI<18.5 kg/m2, a higher HIV disease stage or a CD4 count<350 cells/µL No significant effects observed for weight or CD4 count change.
Serrano et al 2010	Niger PLHIV receiving ART, CD4≤200/ mm3, WHO stage III or IV and/or BMI<18.5 kg/m2 (all PLHIV had been on ART for <12 months)	Intervention group (n=62) compared to historical control group of patients meeting the same eligibility criteria, but who did not receive food assistance (n=118) **Food basket:** 2,250 kcal/person/day per family	ART adherence Survival CD4 count Nutritional status	ART adherence at 6 months (food group vs non food group): 98% vs 77.4% (p<0.05) Increase in CD4 count: +114 vs +68 CD4 cells/mm3 (p<0.05) Survival: 1 death vs 12 deaths (p<0.05) No difference of changes of WHO stage or BMI

Study	Country & Study population	Study design & Food basket	Outcome indicators	Findings
Ivers et al 2010	Haiti PLHIV in care Eligibility based on also having TB, low BMI, low CD4 count (≤350/mm3) and/or severe socio-economic conditions	Prospective observational cohort study, comparing PLHIV (most but not all on ART) eligible for food assistance (n = 300) to those not eligible (n = 300) **Food basket:** 100 g CSB, 50 g cereal, 50 g dried legumes, 25 g vegetable oil, 5 g iodized salt per day per family member, for maximum of three members	Number of monthly visits attended Food security score BMI	Mean number of scheduled monthly visits attended (food-assisted vs non food-assisted): 5.49 vs 2.82 (p<0.0001) *(at 6 months)* 9.73 vs 8.34 (p= 0.007) *(at 12 months)* Change in food insecurity score: -3.55 vs -0.16 (p<0.0001) *(at 6 months)* -3.49 vs -1.89 (p= 0.01) *(at 12 months)* Change in BMI: -0.20 vs -0.66 (p=0.02) *(at 6 months)* 0.22 vs -0.67 (p= 0.04) *(at 12 months)*
Tirivayi et al 2012	Zambia Food-insecure PLHIV on ART	Prospective controlled design: - 4 clinics assigned to food assistance (n=442 PLHIV) - 4 clinics without food assistance (n=194 PLHIV) **Food basket:** amount and type of food varied by family size and income owner status of PLHIV—all received CSB and oil, some also maize meal and beans	MPR from pharmacy refill records Weight gain CD4 count	MPR≥95% among patients in food-assisted clinics vs non food-assisted: 70% vs 48% (RR= 1.5; 95%CI 1.2–1.8) No significant effect on weight gain or CD4 cell response was observed
Posse et al 2013	Mozambique PLHIV with low BMI (\18.5 kg/m2) and no or low income Eligibility reviewed every 3 months	Retrospective study, comparing records from PLHIV on ART in 2 provinces (one with and one without food assistance) Analysis used PSM **Food basket:** monthly, consisting of 25 kg maize, 10 kg soya, 5 kg cowpeas	Adherence to ART, using pharmacy refill records (measured as periods of time during which patient's	Adherence among food recipients vs non food recipients: 0.137 vs 0.182 (p = 0.029) *(during food assistance period)* 0.129 vs 0.199 (p=0.001) *(post food assistance)*

Study	Country & Study population	Study design & Food basket	Outcome indicators	Findings
			medication supply was exhausted)	
Martinez et al 2014	Honduras Locally resident adult PLHIV on ART for >6 months, with indications of suboptimal adherence, being underweight (BMI<18.5 kg/m2) and/or household food insecurity	Prospective clinical trial in four clinics, comparing: (i) Nutrition education (NE) alone (n=197); to (ii) NE + monthly household food basket (FB) (n=203) **Food basket:** calculated for a household of five people for 30 days, with the following daily portions: 1,000 g of maize, 240 g of rice, 370 g of beans, 500 g of fortified CSB, 90 g of vegetable oil (valued at ~USD 46) and provided monthly for 12 months.	Missed clinic appointments Delayed prescription refills Self-reported missed doses of ART	Missing an appointment in the last 6 months: FB: 63.5 % to 18.8 % (p<0.01) *(at 6 mo)* NE: 53.4% to 14.9% (p<0.01) *(at 6 mo)* FB had no significant additional effect at 6 or 12 months Refill delays: FB: 62.5% to 22.6% (p<0.01) *(at 6 mo)* NE: 33.3% to 16.7% (p<0.01) *(at 6 mo)* FB had 19.6 % larger improvement at month 6 (p<0.01) and 11.1 % larger improvement at month 12 (p<0.10) Self-reported missed doses in last month: FB: 40.4% to 6.6% (p<0.01) *(at 6 mo)* NE: 45.0% to 9.2% (p<0.01) *(at 6 mo)* FB had no significant additional effect at 6 or 12 months
McCoy et al 2017	Tanzania Adult PLHIV newly initiated on ART (≤90 days) and food insecure, as measured with the Household Hunger Scale	Individually randomised controlled trial at 3 clinics, comparing (i) Nutritional Assessment and Counselling (standard of care); and (ii) NAC + Food Food receipt was conditional on attending scheduled visits **Food basket:** whole maize meal (12 kg), groundnuts (3 kg), and beans (3 kg) per month (valued at ~USD 11)	Medication Possession Ratio (MPR)≥95% MPR Loss to follow up (LTFU) Appointment attendance	MPR≥95% among food group vs NAC (standard of care): 79.2% vs 63.4% (p<0.01) *(6 months)* 64.0% vs 55.4% (p>0.05) *(12 months)* MPR: 92.9% vs 85.4% (p<0.01) *(6 months)* 89.5% vs 83.3% (p<0.01) *(12 months)* LTFU: 1.5% vs 10.9% (p<0.01) *(6 months)*

Study	Country & Study population	Study design & Food basket	Outcome indicators	Findings
		(There was a second intervention arm with NAC + cash, but we only focus on the NAC + food findings here.)		9.7% vs 17.3% (p>0.05) *(12 months)* Appointment attendance: 94.5% vs 82.6% (p<0.01) *(6 months)* 92.3% vs 83.4% (p<0.01) *(12 months)*
Lamb et al 2012	Cote d'Ivoire, Ethiopia, Kenya, Lesotho, Mozambique, Nigeria, Rwanda, South Africa, Tanzania, Zambia 232,389 PLHIV initiating ART during 2004–2008 at 349 clinics supported by PEPFAR	Ecologic study comparing clinics with and without adherence support and outreach services Clinics self-reported whether they provided food rations to support ART adherence **Food basket:** no details provided	Clinic attrition (Total attrition, LTFU, Death) Cohort attrition	Total attrition: Adjusted RR= 0.72 (95%CI: 0.58–0.90) LTFU: Adjusted RR= 0.65 (95%CI: 0.47–0.88) Death: Adjusted RR= 0.83 (95%CI: 0.69–1.0) Cohort attrition: Adj RR=0.82 (95%CI: 0.64-1.05) *(6 mo)* Adj RR=0.98 (95%CI: 0.78-1.21) *(12 mo)*

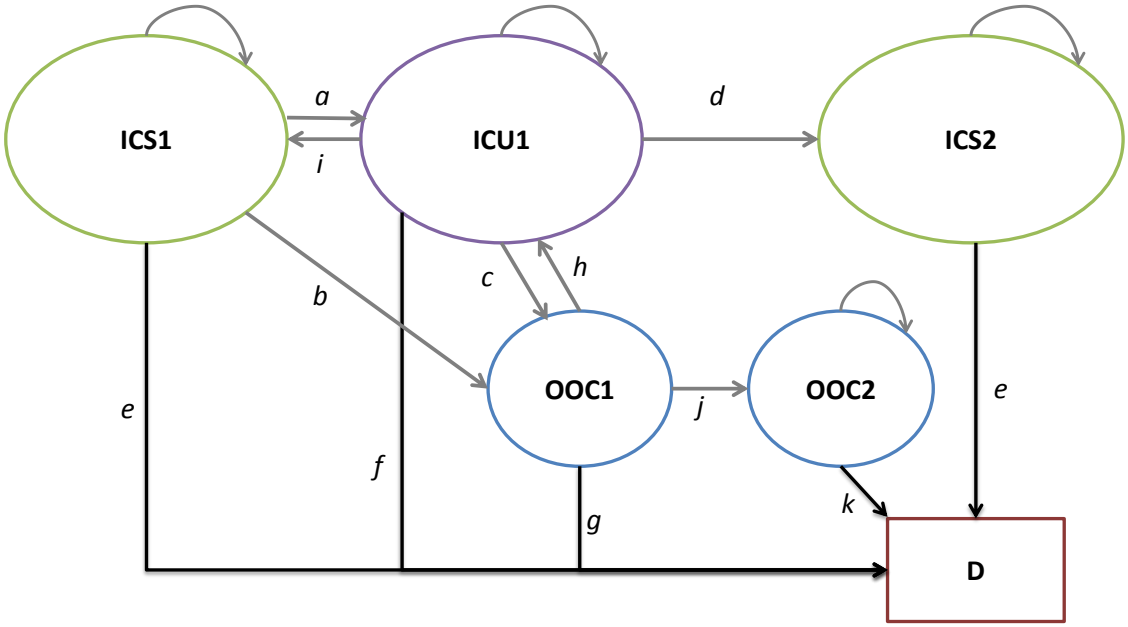
Source: adapted from de Pee et al (2014)(1) and updated.

2. Markov Model

The Markov model consists of the following 6 states:

- In first-line ART Care and virally Suppressed (ICS1)
- In first-line ART Care and virally Unsuppressed (ICU1)
- In second-line ART Care and virally Suppressed (ICS2)
- First state of being Out Of Care with the possibility to return into care (OOC1)
- Second state of being Out Of Care without the possibility to transition back to care (OOC2)
- Death

Figure S1. Markov Model



The transition equations between states are as follows:

$$ICS1_t = (1 - a - b - e) \cdot ICS1_{t-1} + i \cdot ICU1_{t-1}$$

$$ICU1_t = (1 - c - f - d - i) \cdot ICU1_{t-1} + a \cdot ICS1_{t-1} + h \cdot OOC1_{t-1}$$

$$ICS2_t = (1 - e) \cdot ICS2_{t-1} + d \cdot ICU1_{t-1}$$

$$OOC1_t = (1 - g - h - j) \cdot OOC1_{t-1} + b \cdot ICS1_{t-1} + c \cdot ICU1_{t-1}$$

$$OOC2_t = (1 - k) \cdot OOC2_{t-1} + j \cdot OOC1_{t-1}$$

$$D_t = e \cdot ICS1_{t-1} + f \cdot ICU1_{t-1} + e \cdot ICS2_{t-1} + g \cdot OOC1_{t-1} + k \cdot OOC2_{t-1}$$

Table S2. Description of Transition Probabilities

Transition probability	Description
a	Probability of virologic failure when in care (first and second-line ART) and virally suppressed
b	Probability of disengaging from care when in first-line ART care and virally suppressed
c	Probability of disengaging from care when in first-line ART care and unsuppressed
d	Probability of switching to second-line care if in first-line ART care and unsuppressed
e	Probability of dying if in care and virally suppressed
f	Probability of dying if in care and unsuppressed
g	Probability of dying if out of care for one cycle
h	Probability of re-entering first-line care after disengaging for one cycle
i	Probability of achieving viral suppression after being in care but unsuppressed for one cycle
j	Probability of remaining out of care after being disengaged for one cycle
k	Probability of dying if out of care for more than one consecutive cycle

3. Modelling Secondary Sexual HIV Transmission

We developed a simple static HIV transmission model to estimate new sexually transmitted secondary infections from the cohort of patients to their sex partners over their lifetime, in the five countries. New sexually transmitted infections were estimated for each cycle by multiplying the susceptible population by the probability of becoming infected. We did not consider non-sexual transmission.

The susceptible population for secondary HIV infection was the average number of HIV-negative sexual partners per person in the cohort population, multiplied by the number of people in the cohort that was alive in each cycle (and aged <60 years). Since the cycles are half a year, we conservatively assumed half of the annual number of partners per cycle.

We estimated new infections among the sexual partners of people in the virally suppressed states (IC1 and IC2) on the one hand, and new infections among the sexual partners of people

in the unsuppressed states (ICU1, OOC1 and OOC2) on the other. Those who died in a given cycle were assumed to not have been sexually active during that cycle.

We used a similar risk equation to the one used in other models (2, 3) to calculate the probability of transmission to an uninfected partner during one year, given by:

$1 - [P\times (1 - r \times R \times M_{MC} \times M_C)^a + (1 - P)]^n$

Where

P= HIV prevalence in the partner population
r = Base probability of HIV transmission per act
R = Multiplier for the effect of stage of infection
M_{MC} = Multiplier for the effect of male circumcision
M_C = Multiplier for the effect of condom use
a = Number of acts per partner per year
n = Number of partners per year

We estimated one average probability for those mixing with the virally suppressed populations, and another for those mixing with the unsuppressed. This assumes that the cohort and their sexual partners are representative of the entire population in terms of risk characteristics. We calculated the weighted average of the number of acts per partner per year and the number of partners per year, assuming an equal mix of males and females.

For example, the average number of partners per year, n, is given by:

$$n = \sum_{k=l,m,h}^{\cdot} s_k \, n_k$$

Where
n_k= the number of partners in each risk group *k* (low, medium, high)
s_k = the share/proportion of the population in risk group *k*

We included the effect of exogenous protective interventions, namely treatment, male circumcision and condom use. For these interventions, *x*, we assume the multiplier effect, M_x, is 1 minus the average HIV protection, which is a function of its efficacy, E_x, and coverage C_x:

$$M_x = 1 - E_x C_x$$

For those mixing with the virally suppressed group, the multiplier for the effect of stage of infection, *R*, was equivalent to the multiplier effect of effective ART, M_T. For those mixing with the unsuppressed group, R was equivalent to that used for symptomatic patients.

Table S3. Country parameters and estimates of the probability of transmission

	Tanzania	Zambia	Ethiopia	Lesotho	South Africa
Underlying variables[1]					
Male circumcision coverage	0.84	0.37	0.76	0.69	0.56
Condom use	0.27	0.17	0.08	0.29	0.52
Proportion of sexually active population categorized as low risk heterosexual	0.53	0.71	0.86	0.54	0.52
Proportion of sexually active population categorized as medium risk heterosexual	0.40	0.26	0.10	0.41	0.40
Proportion of sexually active population categorized as high risk (heterosexual, MSM, IDU)	0.06	0.03	0.04	0.05	0.08
Number of partners per year (low risk)	1	1	1	1	1
Number of partners per year (medium risk)	4.6	2.5	1.2	2	4.5
Number of partners per year (high risk)	87.5	54.5	76	32	105
Number of sex acts per partner (low risk)	54	75	40	90	90
Number of sex acts per partner (medium risk)	22	60	12	30	41
Number of sex acts per partner (high risk)	2	3	2	3	1.5
Equation variables					
HIV prevalence in partner population	0.05	0.14	0.02	0.23	0.19
Base probability of HIV transmission per act[2]	0.0033	0.0033	0.0033	0.0033	0.0033
Multiplier for the effect of stage of infection (symptomatic)[3]	4.45	4.45	4.45	4.45	4.45
Multiplier for the effect of condom use[4]	0.79	0.86	0.94	0.77	0.67
Multiplier for the effect of male circumcision[5]	0.50	0.78	0.54	0.59	0.66
Multiplier for the effect of treatment[6]	0.04	0.04	0.04	0.04	0.04
Number of acts per partner per year	38	69	36	61	63
Number of partners per year	8	3	4	3	11
Number of susceptible partners per year	8	3	4	2	9
Estimated Probability of transmission per person					
Annual probability (suppressed group)	0.001	0.003	0.0001	0.002	0.008
Probability per 6-month cycle[5] (suppressed group)	0.0004	0.0014	0.0001	0.0012	0.004
Annual probability (unsuppressed group)	0.071	0.204	0.014	0.211	0.515
Probability per 6-month cycle[5] (unsuppressed group)	0.036	0.108	0.007	0.112	0.304

Notes: [1]All of these values are extracted from Spectrum (2); [2] Boily et al, 2009 (4); [3]The efficacy of condom use is 0.85 (5, 6); [3]The efficacy of male circumcision is 0.6 (7) and [4]The efficacy of effective treatment is 0.96 (8). The 6-month probability = 1-(1-annual probability)$^{1/2}$.

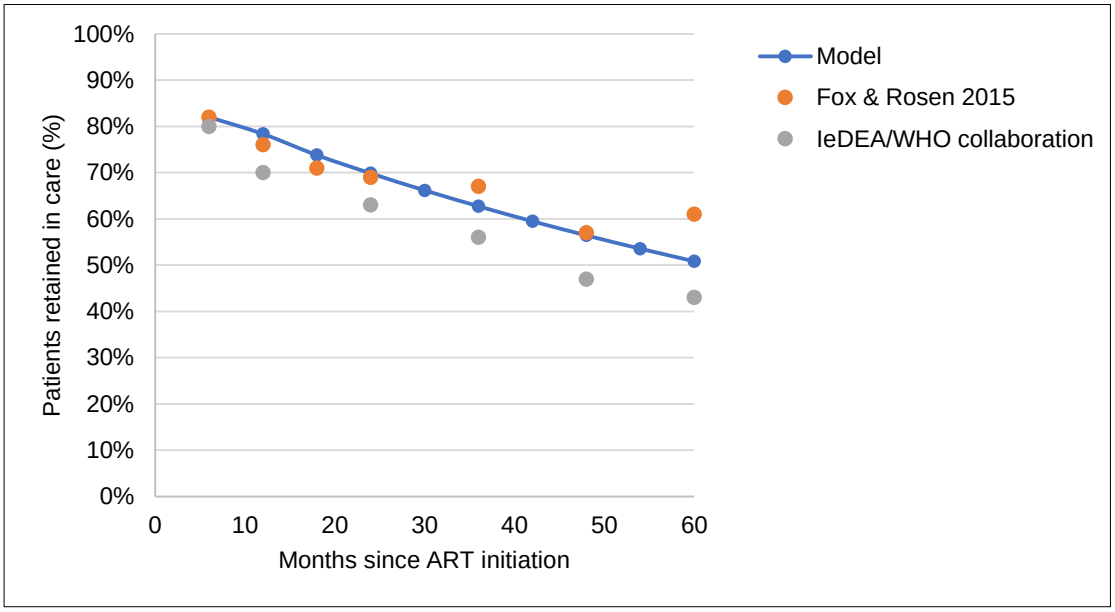
4. Cohort simulations and Markov Model Calibration

The model was calibrated to: (1) retention in care data from a meta-analysis of sub-Saharan African ART cohorts by Fox & Rosen (2015) (9); (2) HIV-specific mortality rates for ART patients since initiation from Murray et al (2014) (10); and (3) on-treatment viral suppression data from a meta-analysis of ART cohorts in LMICs by Boender et al (2015) (11).

Since the parameters for transition probabilities were taken from averages across sub-Saharan Africa, the outputs were nearly identical across countries, with some minor variation for

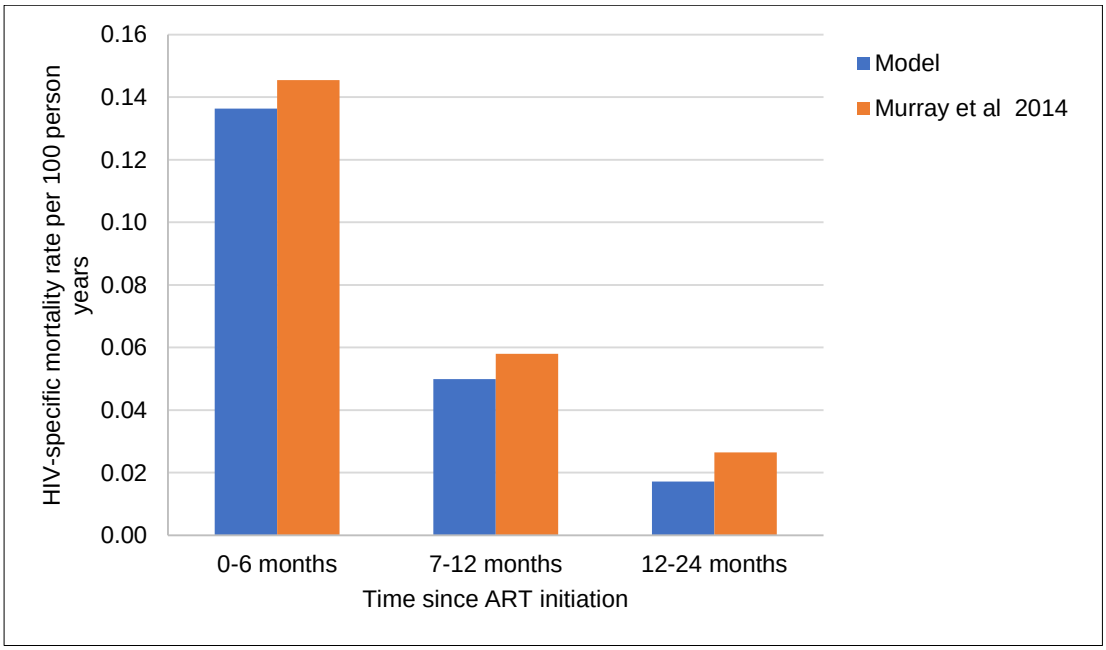
Lesotho. The only transition probabilities that varied per country were other-cause mortality when virally suppressed, and rates of change in mortality derived from the latter.

Figure S2. Comparison of model output with observed data for Retention in care



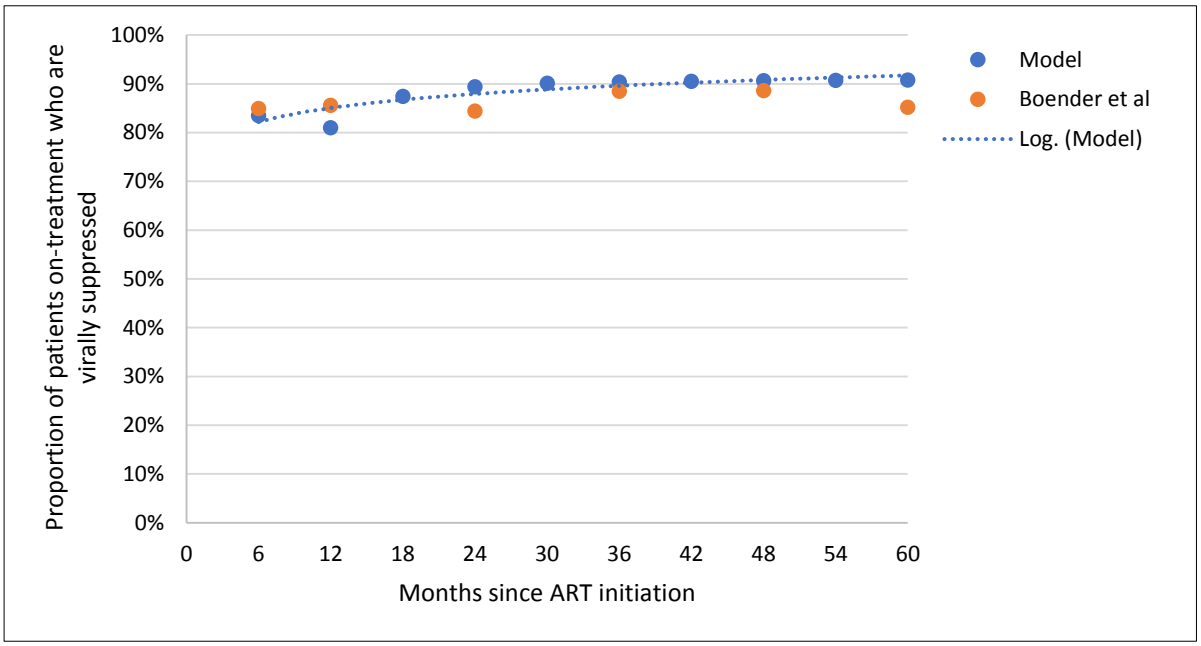
Note: Observed data from IeDEA/WHO for Southern Africa (12) are included for illustration, but were not used for calibration.

Figure S3. Comparison of model output with observed data for HIV-specific mortality rates



Note: Murray et al (2014) is averaged across sexes and for initial CD4 count between 200-249, for sub-Saharan Africa.

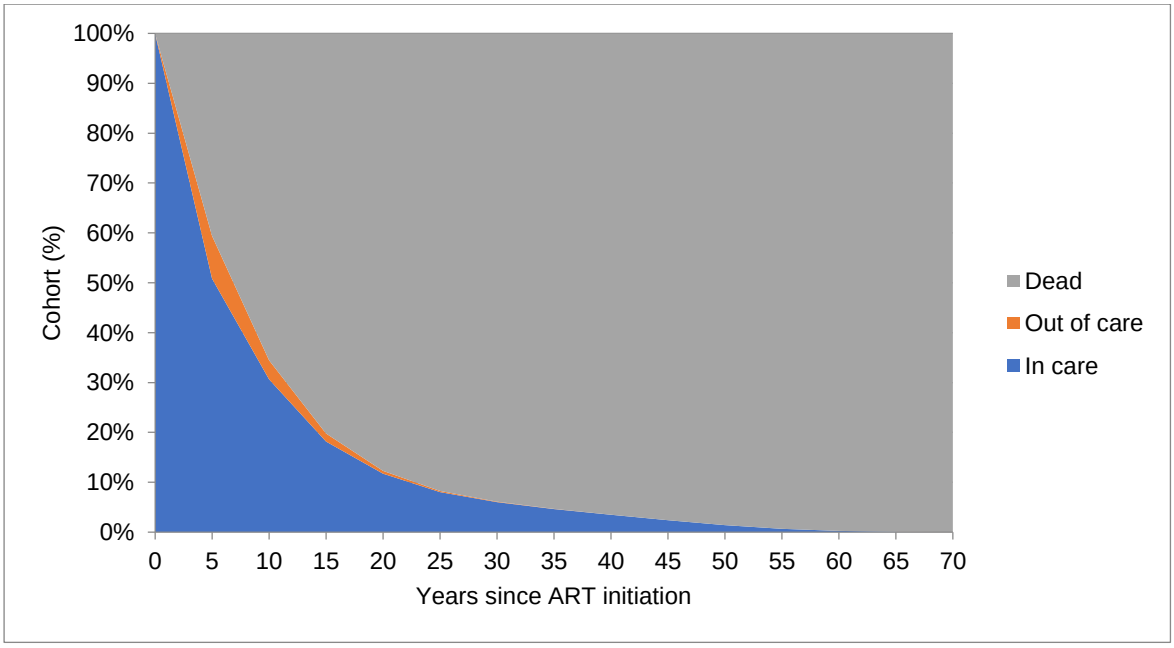
Figure S4. Comparison of model output with observed data for On-treatment Viral suppression



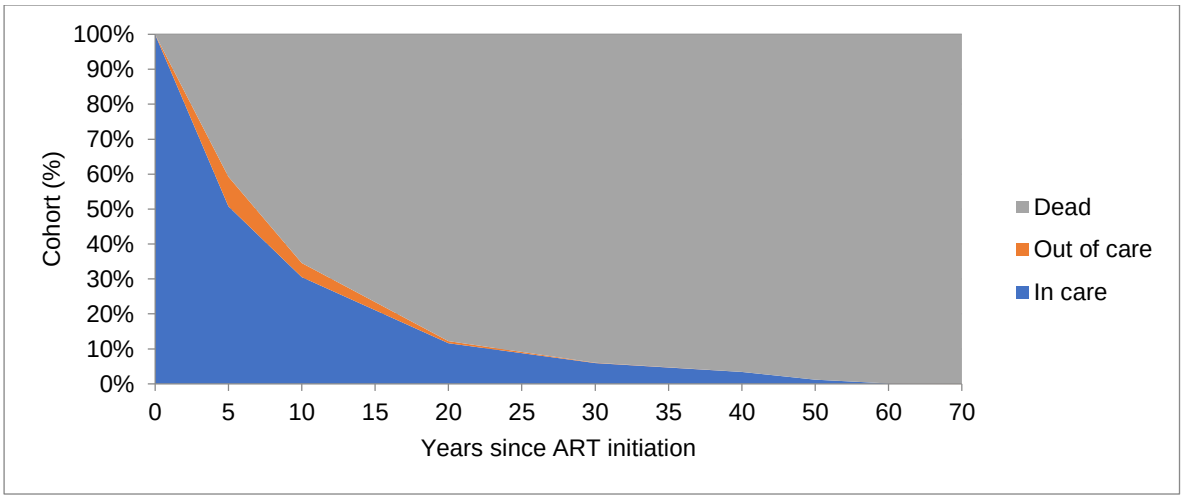
Below are figures with the model outputs for each country from running the model until the cohort dies in the baseline scenario without the intervention and then with the intervention, as well as tables with the model outputs for the first 5 years after ART initiation. These consider the health of the cohort, and do not yet factor in secondary HIV transmission.

Figure S5. Model simulation without intervention

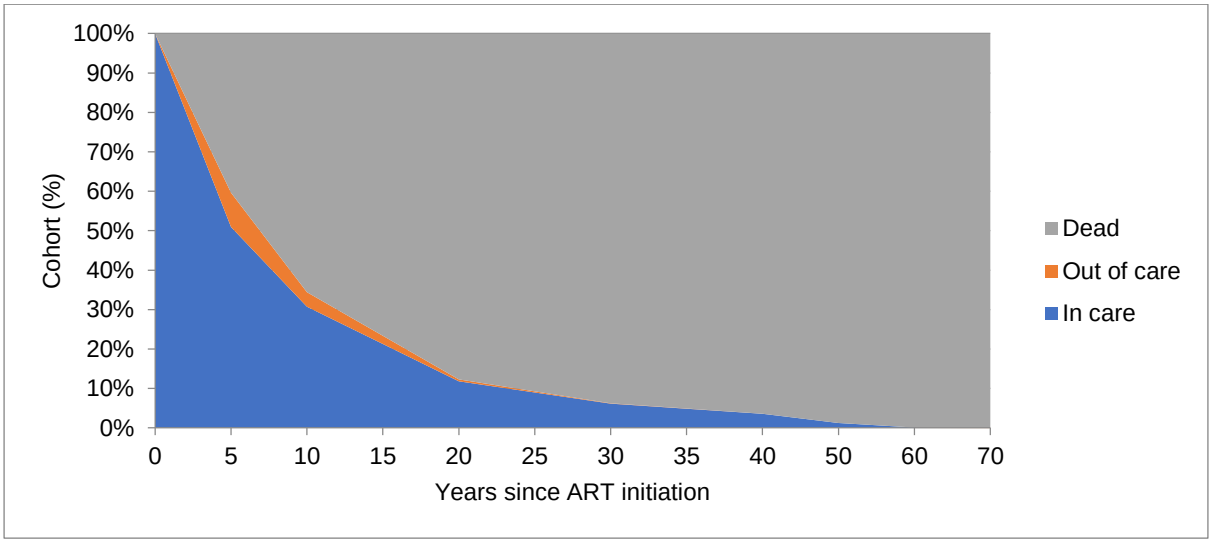
a) Tanzania



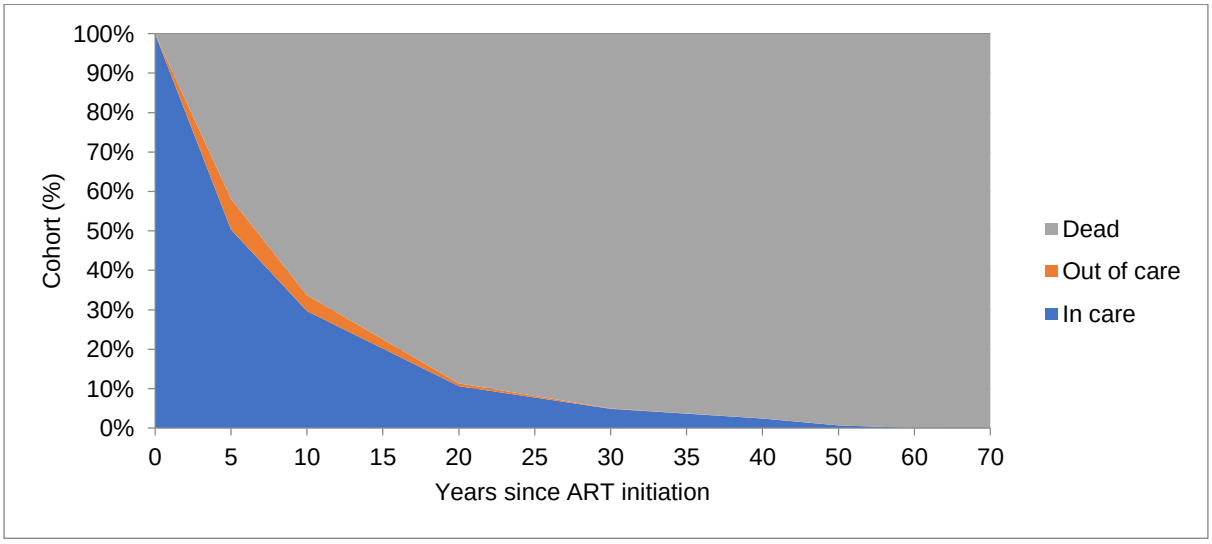
b) Zambia



c) Ethiopia



d) Lesotho



e) South Africa

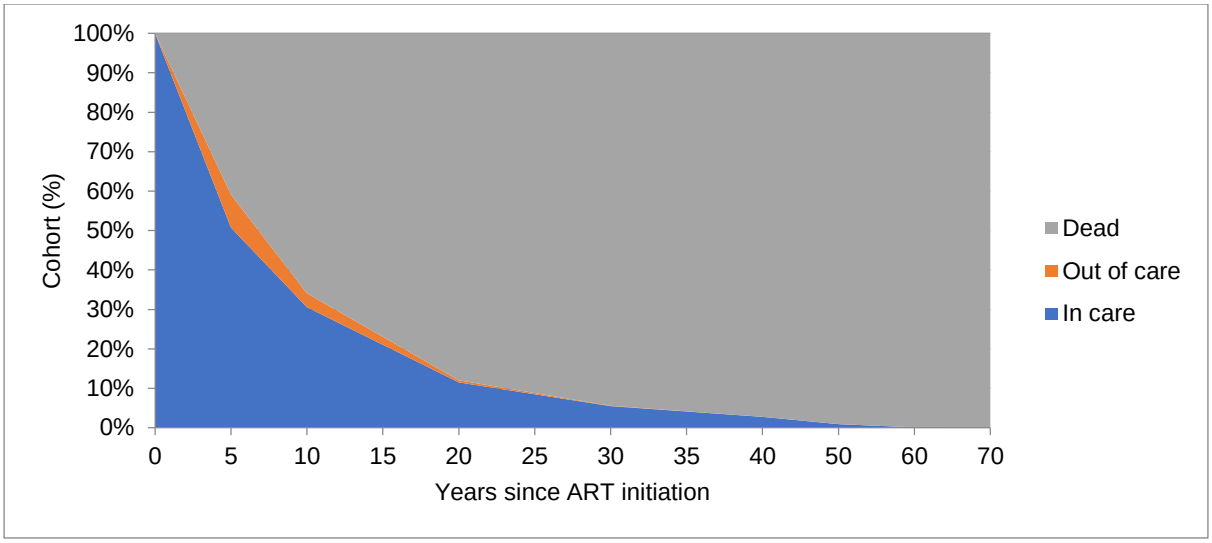


Table S4. Model simulation without intervention until 5 years (10 cycles) post-initiation

a) Tanzania

	Cycle									
	1	2	3	4	5	6	7	8	9	10
Alive	934	884	845	806	768	731	694	659	626	594
Dead	66	50	39	39	38	38	36	35	33	32
Life years	17	12	10	10	10	9	9	9	8	8
Suppressed	685	635	645	624	596	567	539	511	486	461
Unsuppressed	249	250	200	182	172	164	156	148	140	133
ICS1	685	629	632	608	576	544	513	483	456	429
ICU1	135	149	93	74	65	60	56	53	50	47
ICS2	-	6	13	17	20	23	25	28	30	32
Retained in care	820	784	738	698	662	627	595	564	536	508

b) Zambia

	Cycle									
	1	2	3	4	5	6	7	8	9	10
Alive	934	884	845	806	767	729	693	658	624	593
Dead	66	50	40	39	39	38	37	35	33	32
Life years	17	12	10	10	10	9	9	9	8	8
Suppressed	685	635	645	624	596	567	538	511	485	461
Unsuppressed	249	250	200	181	171	163	155	147	139	132
ICS1	685	629	632	608	576	544	513	483	455	429
ICU1	135	149	93	74	65	60	56	53	50	47
ICS2	-	6	13	17	20	23	25	28	30	32
Retained in care	820	784	738	698	661	627	594	564	535	508

c) Ethiopia

	Cycle									
	1	2	3	4	5	6	7	8	9	10
Alive	934	884	846	808	770	732	696	661	628	596
Dead	66	50	39	38	38	37	36	35	33	32
Life years	17	12	10	10	10	9	9	9	8	8
Suppressed	685	635	645	624	596	567	539	512	486	462
Unsuppressed	249	250	201	183	173	165	157	150	142	134
ICS1	685	629	632	608	576	544	513	484	456	430
ICU1	135	149	93	74	66	60	57	53	50	47
ICS2	-	6	13	17	20	23	26	28	30	33
Retained in care	820	784	738	699	662	628	595	565	536	509

d) Lesotho

	Cycle									
	1	2	3	4	5	6	7	8	9	10
Alive	934	884	841	800	760	721	683	647	613	581
Dead	66	50	43	41	40	39	37	36	34	32
Life years	17	12	11	10	10	10	9	9	9	8
Suppressed	685	635	645	624	596	566	536	509	482	457
Unsuppressed	249	250	196	176	164	155	147	139	131	124
ICS1	685	629	632	608	576	543	512	482	453	426
ICU1	135	149	93	73	64	59	55	52	49	46
ICS2	-	6	13	17	20	22	25	27	29	31
Retained in care	820	784	738	697	660	625	591	560	531	503

e) South Africa

	Cycle									
	1	2	3	4	5	6	7	8	9	10
Alive	934	884	844	805	766	728	692	657	623	591
Dead	66	50	40	39	39	38	37	35	34	32
Life years	17	12	10	10	10	10	9	9	8	8
Suppressed	685	635	645	624	596	567	538	511	485	461
Unsuppressed	249	250	199	181	170	162	154	146	138	131
ICS1	685	629	632	608	576	544	513	483	455	429
ICU1	135	149	93	74	65	60	56	53	50	47
ICS2	-	6	13	17	20	23	25	28	30	32
Retained in care	820	784	738	698	661	627	594	563	534	507

Figure S6. Model simulation with Intervention

a) Tanzania

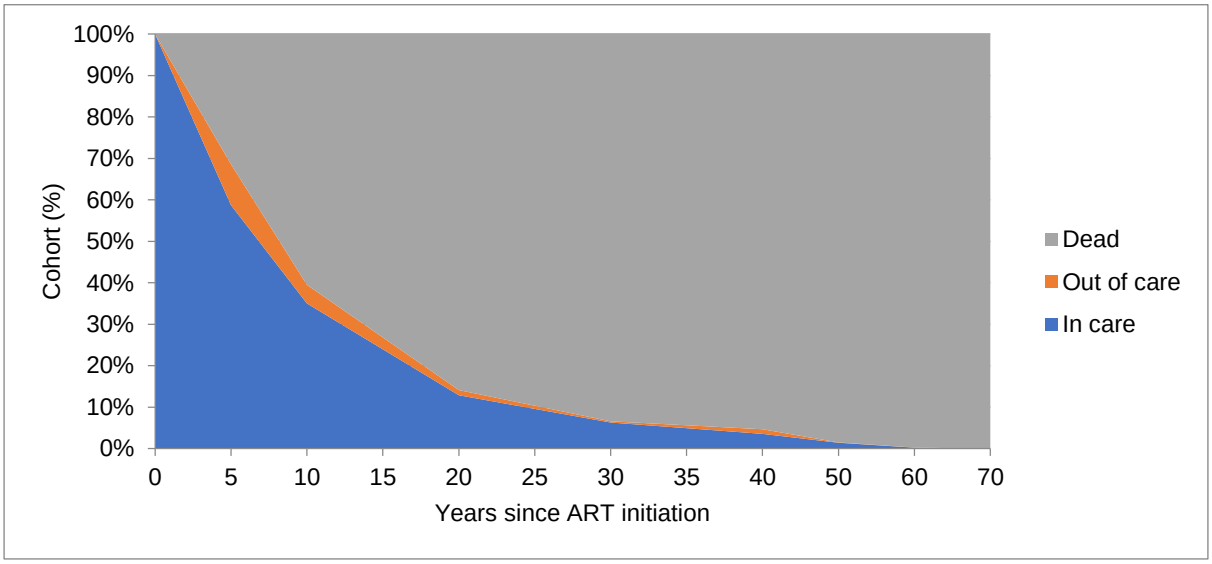


Table S5. Model simulation with Intervention until 5 years (10 cycles) post-initiation

a) Tanzania

	Cycle									
	1	2	3	4	5	6	7	8	9	10
Alive	991	964	942	911	876	837	799	760	722	686
Dead	9	27	22	31	36	38	39	39	38	36
Life years	2	7	6	8	9	10	10	10	9	9
Suppressed	961	795	767	730	692	657	623	591	561	532
Unsuppressed	30	169	175	182	183	181	176	169	162	154
ICS1	961	795	761	720	679	640	603	568	536	505
ICU1	14	112	89	81	75	70	66	62	59	55
ICS2	-	1	6	10	13	16	20	22	25	28
Retained in care	975	907	856	810	767	727	689	653	619	587

b) Zambia

	Cycle									
	1	2	3	4	5	6	7	8	9	10
Alive	991	964	941	910	874	836	797	758	721	684
Dead	9	27	23	31	36	38	39	39	38	36
Life years	2	7	6	8	9	10	10	10	9	9
Suppressed	961	795	767	730	692	657	623	590	560	532
Unsuppressed	30	169	174	181	182	180	174	168	160	153
ICS1	961	795	761	720	679	640	603	568	535	504
ICU1	14	112	89	80	75	70	66	62	58	55
ICS2	-	1	6	10	13	16	19	22	25	27
Retained in care	975	907	856	810	767	727	688	652	619	587

c) Ethiopia

	Cycle									
	1	2	3	4	5	6	7	8	9	10
Alive	991	964	943	913	877	840	801	762	725	689
Dead	9	27	21	30	35	38	39	38	38	36
Life years	2	7	5	8	9	10	10	10	9	9
Suppressed	961	795	767	730	693	657	623	591	561	533
Unsuppressed	30	169	176	183	185	183	178	171	164	156
ICS1	961	795	761	720	679	640	604	569	536	505
ICU1	14	112	89	81	75	70	66	62	59	55
ICS2	-	1	6	10	13	16	20	22	25	28
Retained in care	975	907	856	810	768	727	690	654	620	588

d) Lesotho

	Cycle									
	1	2	3	4	5	6	7	8	9	10
Alive	991	964	937	903	865	826	786	746	708	671
Dead	9	27	27	34	38	40	40	39	38	37
Life years	2	7	7	9	10	10	10	10	10	9
Suppressed	961	795	767	730	692	655	621	588	557	528
Unsuppressed	30	169	170	174	174	170	165	158	151	143
ICS1	961	795	761	720	679	639	601	566	533	501
ICU1	14	112	89	79	73	69	64	61	57	54
ICS2	-	1	6	10	13	16	19	22	24	27
Retained in care	975	907	856	809	765	724	685	648	614	581

e) South Africa

	Cycle									
	1	2	3	4	5	6	7	8	9	10
Alive	991	964	941	909	873	835	796	757	719	683
Dead	9	27	23	31	36	38	39	39	38	36
Life years	2	7	6	8	9	10	10	10	9	9
Suppressed	961	795	767	730	692	656	622	590	560	531
Unsuppressed	30	169	174	180	181	178	173	167	159	151
ICS1	961	795	761	720	679	640	603	568	535	504
ICU1	14	112	89	80	75	70	66	62	58	55
ICS2	-	1	6	10	13	16	19	22	25	27
Retained in care	975	907	856	810	767	726	688	652	618	586

5. Calculation of DALYs and ART cost savings per HIV infection averted

A Disability-Adjusted Life Year (DALY) is a summary measure of disease burden that combines, for a specific disease or condition, the number of years of life lost due to premature mortality

(YLL) with that of years of life lost due to disability (YLD). We adopted the approach in the latest Global Burden of Disease 2010 (13), by removing age-weighting. However, DALYs were discounted at 3% in the main analysis, and at 0% and 6% in the sensitivity analysis.

To estimate DALYs associated with achieving viral suppression, we used the disability weights from Salomon et al (2012) for the health state of HIV/AIDS receiving ART (0.053) and for those that were unsuppressed, we assumed less disability than not being on treatment and similar to being symptomatic but pre-AIDS (0.221). After death, a disability weight of one was assigned until individuals reached their natural death according to their expectation of life.

Table S6. DALY Parameters

Parameters	Value	Source
Discount rate	3%	Murray et al, 2012 (13)
Disability weight pre- AIDS	0.221	Salomon et al, 2012 (14)
Disability weight AIDS – no ART	0.547	
Disability weight AIDS receiving ART	0.053	
Duration pre-AIDS	7 years	Hogan et al, 2005 (15)
Duration AIDS (no ART)	2 years	Cleary et al, 2008 (16)
Age of onset of HIV (ART)	Cycle dependent	Assumes cohort sexual partners are the same age as the cohort individuals in each cycle
Expectation of life	Cycle and country-specific	WHO life tables

We conservatively assume full ART coverage and no premature death due to AIDS from infections averted. Years of life lived in disability (YLD) were low since they only included 2 years of symptomatic pre-AIDS disability, followed by the remaining expected years of life with a low disability weight associated with being on ART.

ART cost savings

The estimate of discounted lifetime ART costs was sourced from a study in South Africa [84]. It was assumed that 50% of the costs were drug costs and therefore fixed across countries. The remaining 50% were adjusted by log GDP per capita. This discounted lifetime ART cost was multiplied by the number of infections averted in each cycle in each country (until cycle 50 or until the cohort reached 60 years of age) to estimate cost savings from any prevented transmission, or incremental costs from additional transmission.

6. Intervention Costs

AFYA Study

The AFYA study was an individually randomised controlled trial conducted by the University of California, Berkeley and the Ministry of Health & Social Welfare in the Shinyanga region in Tanzania (17). It assessed three delivery models for short-term food and nutrition support for people living with HIV: nutrition assessment and counselling (NAC) alone (the standard of care), NAC plus food assistance, and NAC plus cash transfers. In the latter group, food-insecure patients received a standard household food ration, including whole maize meal (12 kg), groundnuts (3kg) and beans (3kg), with a financial value of approximately US$ 11 per month.

The study sought to compare the effect of the combined NAC and food or cash assistance programme (both arms) versus NAC alone on retention in care and ART adherence, measured as the proportion of patients with medication possession ratio ≥95% during the 0-6 month interval. The intervention was provided for enrolled participants from December 2013 to February 2016, with 345 participants enrolled in the food basket arm (18).

Costing Methods

A combination of standard step-down and ingredients costing was used to estimate the financial and economic costs of providing the food basket. Only the provider intervention costs are considered in this analysis, since the indirect provider costs at the health facility level from increased health service utilisation are included elsewhere in the modelling.

We collected intervention cost data at the 3 study sites, namely Shinyanga Regional Hospital, Kahama District Hospital and Kambarage Health Centre, as well as from the research team at the University of California, Berkeley and at the Ministry of Health and Social Welfare. Data was collected in August-September 2015 for the start-up period (1 January 2013 to 30 November 2013) and for the intervention period from 1 December 2013 till 29 February 2016.

Costs were categorised as recurrent and capital costs. Capital costs were annuitized using a discount rate of 3%. Input prices were obtained from the project, health facilities and regional office financial records, as well as local suppliers. Costs were estimated in Tanzanian Shillings (TZS) and then converted into 2015 USD, using weighted average annual Bank of Tanzania Interbank Foreign exchange rates, and the United States GDP deflator for costs incurred in 2013 and 2014.

Research costs were excluded in both the start-up and implementation phases. To be conservative, start-up costs were included in full in total intervention costs, as it was not possible to determine whether and which of these costs would yield benefits beyond the duration of the study.

All project overhead and intervention costs were allocated based on estimated use for the following activities: project administration and management; research; client identification;

monitoring conditionality; cash transfer; and food basket. Overhead costs were allocated using step-down allocation to support cost centres, and then to the final cost centres, namely the Food basket and the Cash transfer. Staff time allocation between activities was estimated from a combination of self-assessments, interviews and time sheets, and used to allocate overheads. The proportion of beneficiaries receiving food baskets was used to allocate the support costs of client identification and conditionality monitoring.

Ethical clearances were received from the Tanzanian National Institute of Medical Research (NIMR), the University of California, Berkeley's Institutional Review Board, and the LSHTM Research Ethics Committee.

Cost estimates

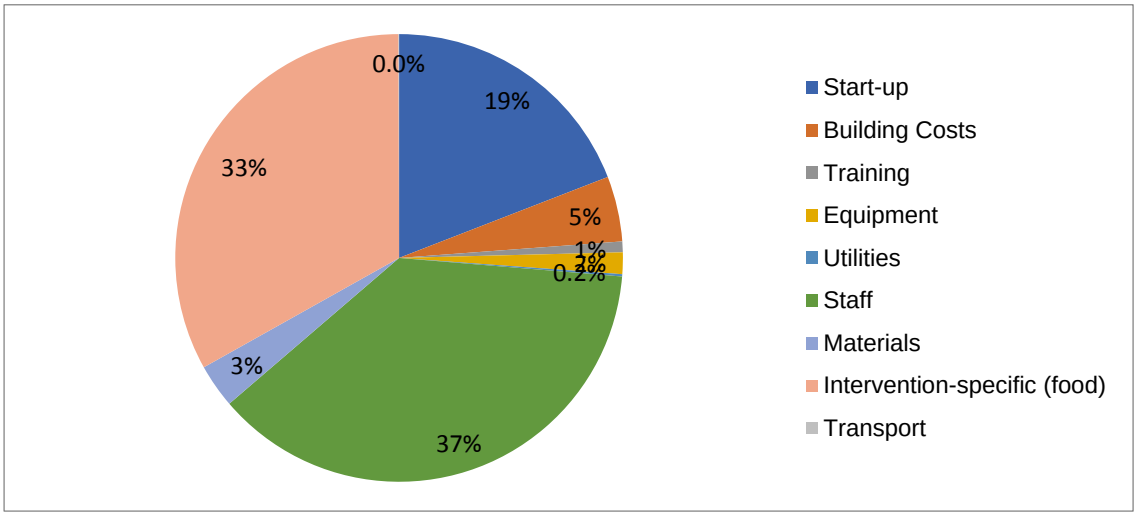
As presented in table S6 below, the total cost of the food basket intervention was estimated at USD 68,205. By the end of the intervention, the food basket had been provided to 345 enrolled patients, at a unit cost of USD 198.

The main cost drivers were recurrent staff costs (38% for the food basket), followed by the food basket procurement cost (30%). Start-up implementation costs were also a major cost category, representing 23% of the total.

Table S7. Estimated Economic Costs for the Food basket intervention

Cost Category	Total (USD)	% of Total
Capital		
Start-up	13,035	**19%**
Building Costs	3,214	**5%**
Training	530	**1%**
Equipment	1,063	**2%**
Total Capital Costs	**17,842**	**26%**
Recurrent		
Utilities	112	**0%**
Staff	25,499	**37%**
Materials	2,159	**3%**
Food procurement	22,563	**33%**
Transport	30	**0%**
Total Recurrent Costs	**50,363**	**74%**
TOTAL COSTS	**68,205**	**100%**

Figure S7. Cost breakdown

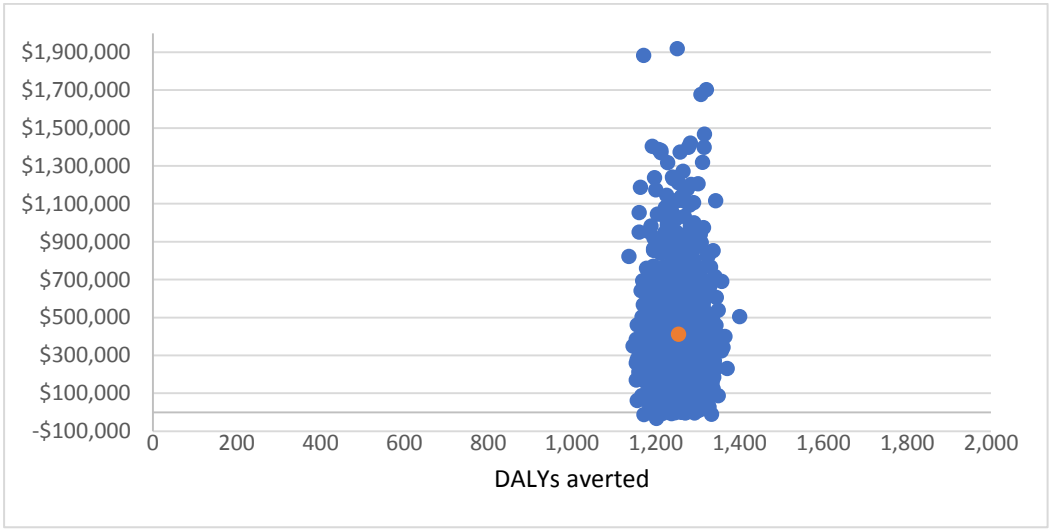


7. Probabilistic Sensitivity Analysis

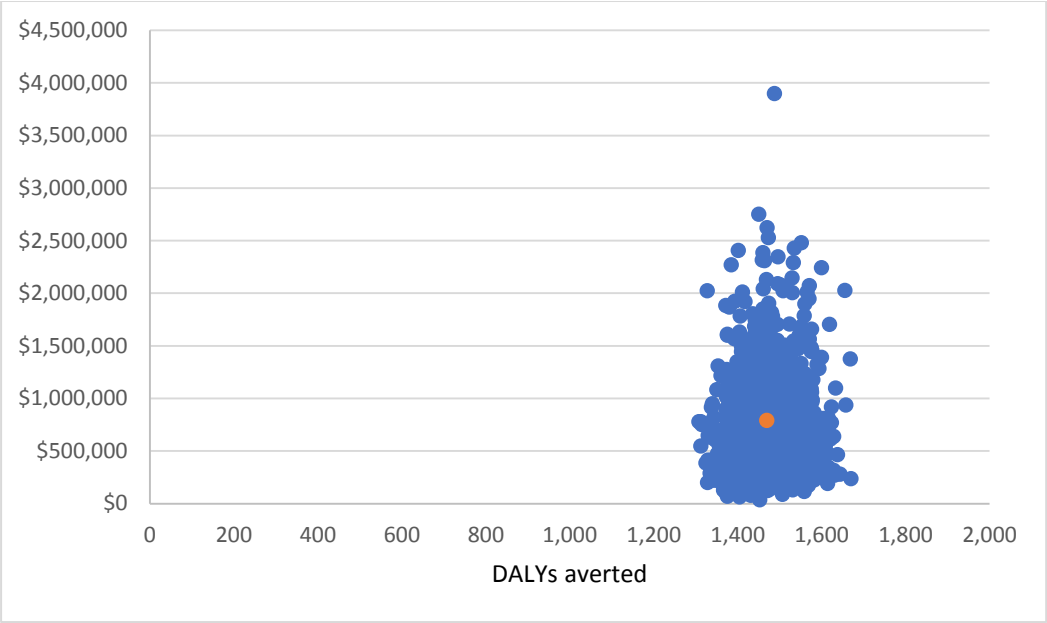
The parameter ranges and distributions used in the PSA are provided in Table 1 in the manuscript. Below are the cost-effectiveness planes for each country from the health care perspective without transmission, with transmission and from the multi-sectoral perspective.

Figure S8. Cost-effectiveness planes: Health care cohort perspective without transmission

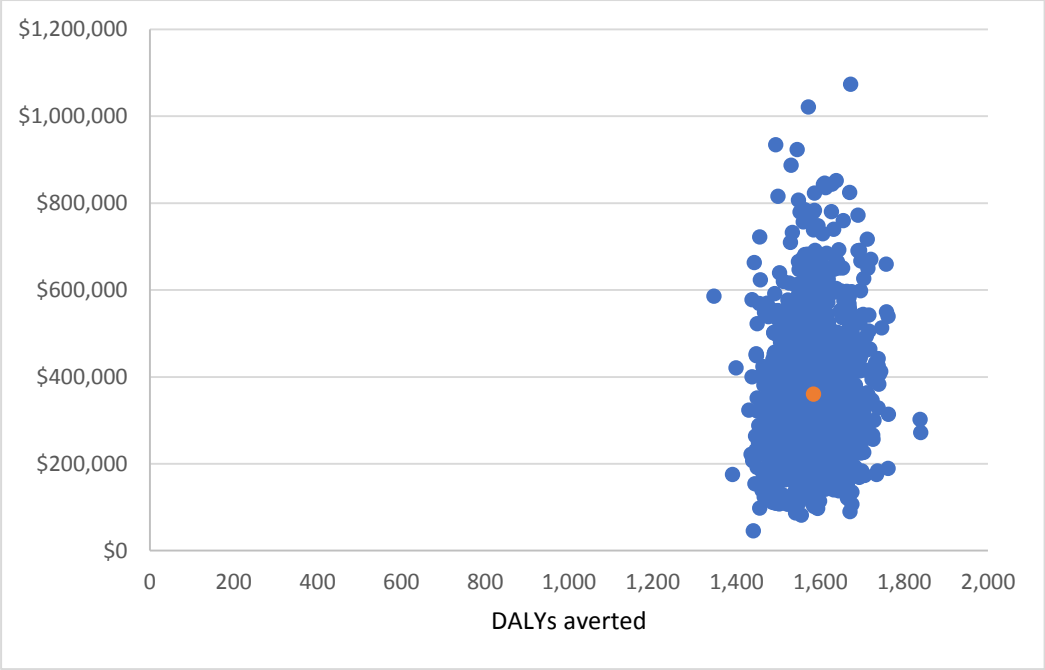
a) Tanzania



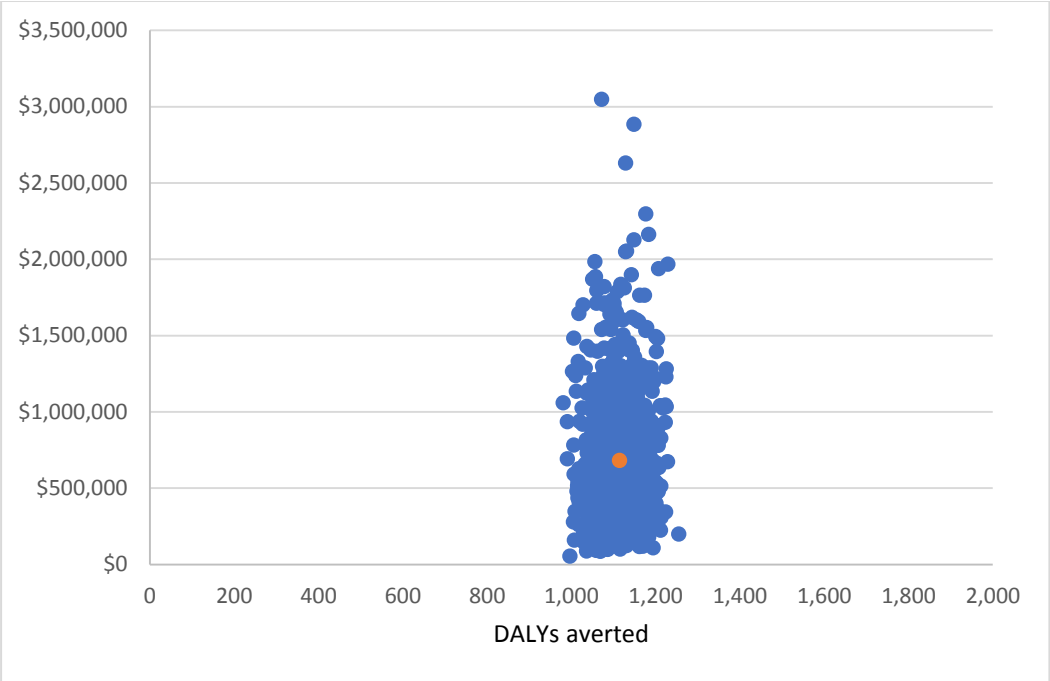
b) Zambia



c) Ethiopia



d) Lesotho



e) South Africa

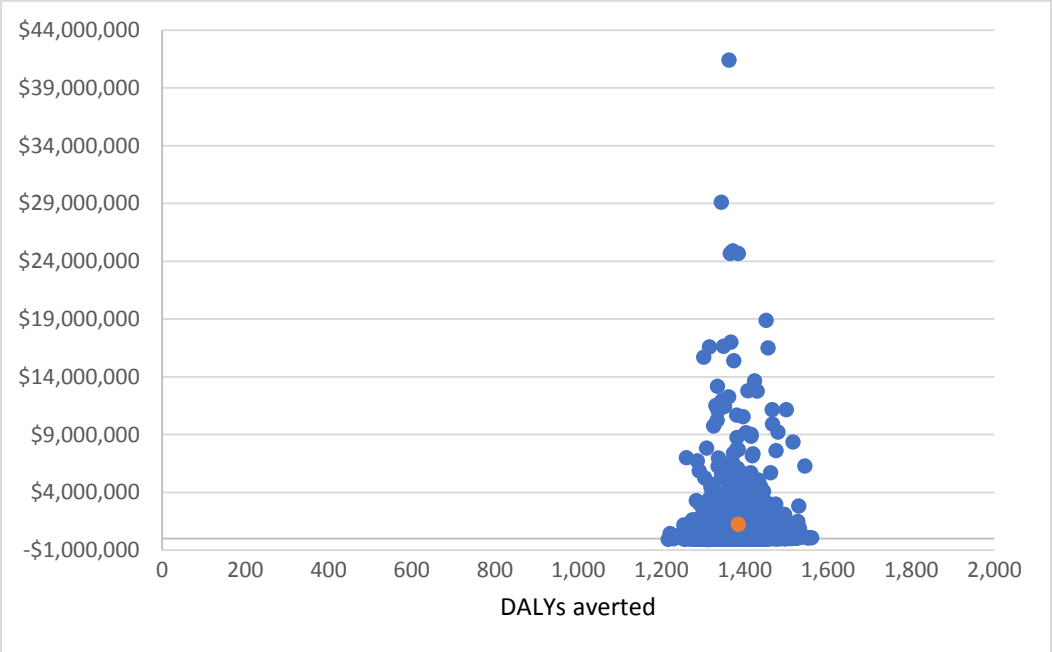
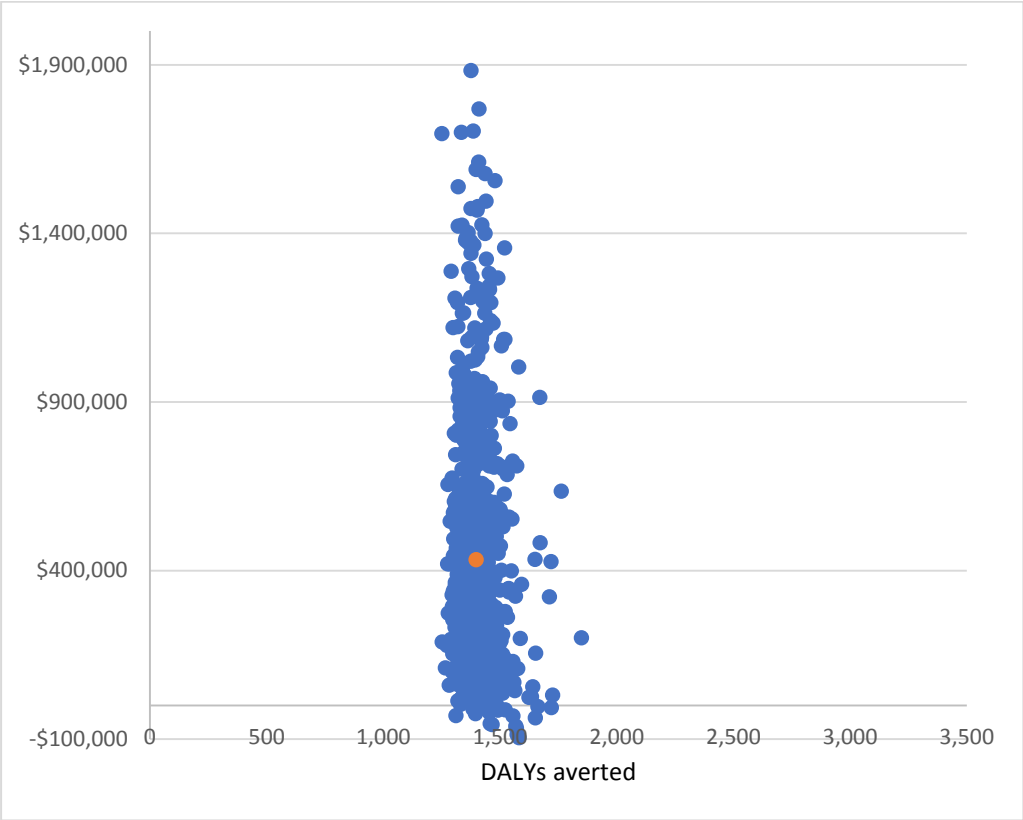
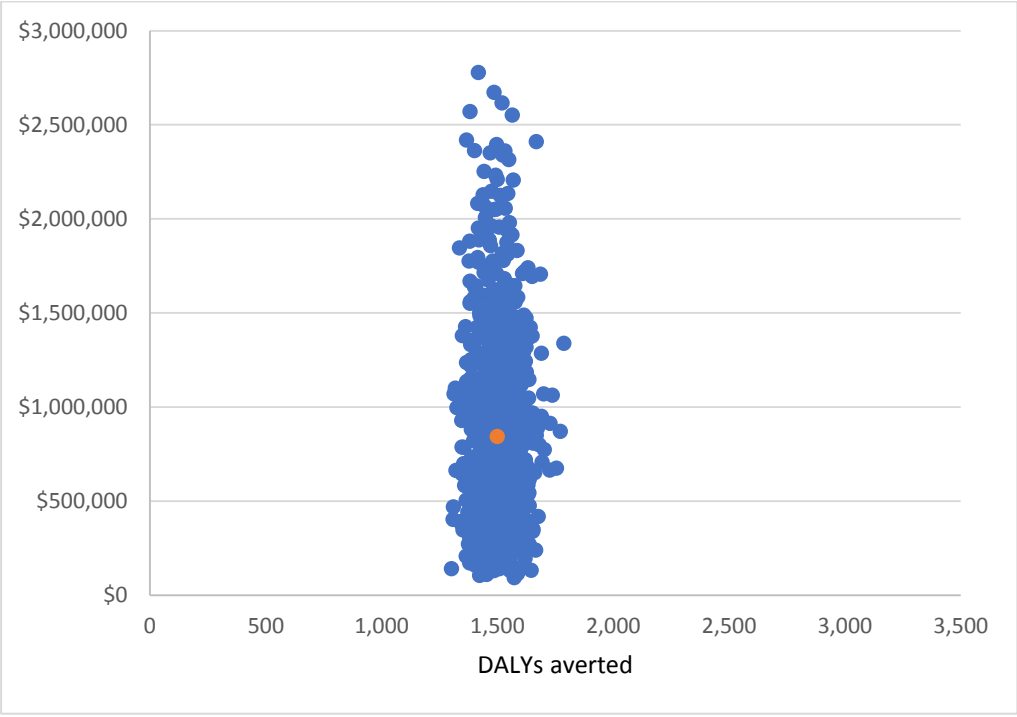


Figure S9. Cost-effectiveness planes: Health care perspective with transmission

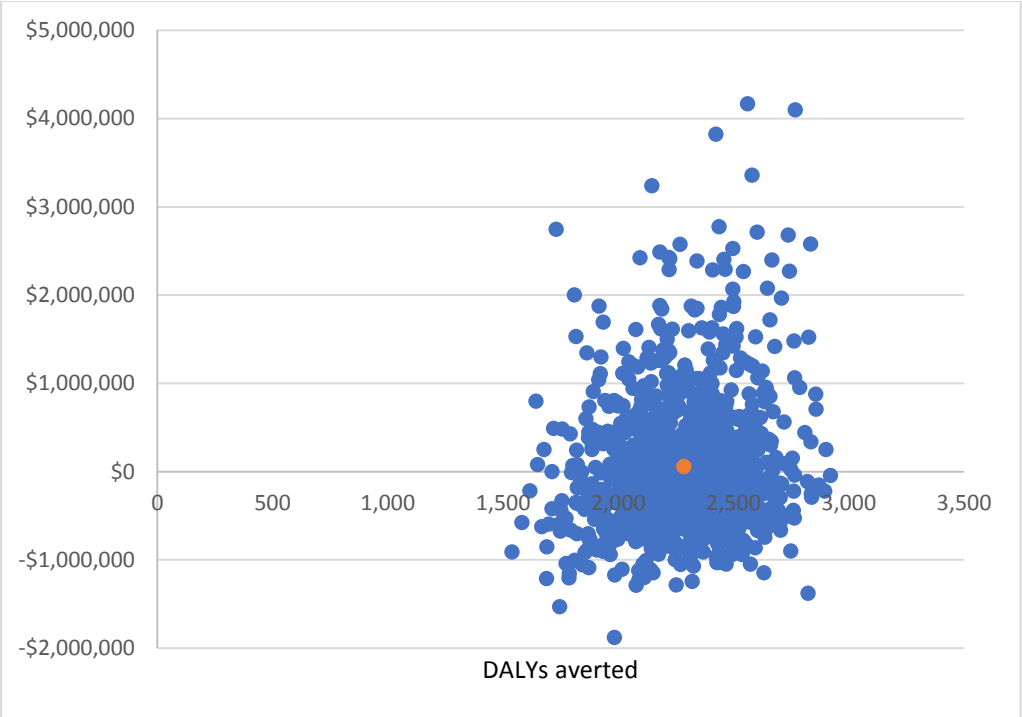
a) Tanzania



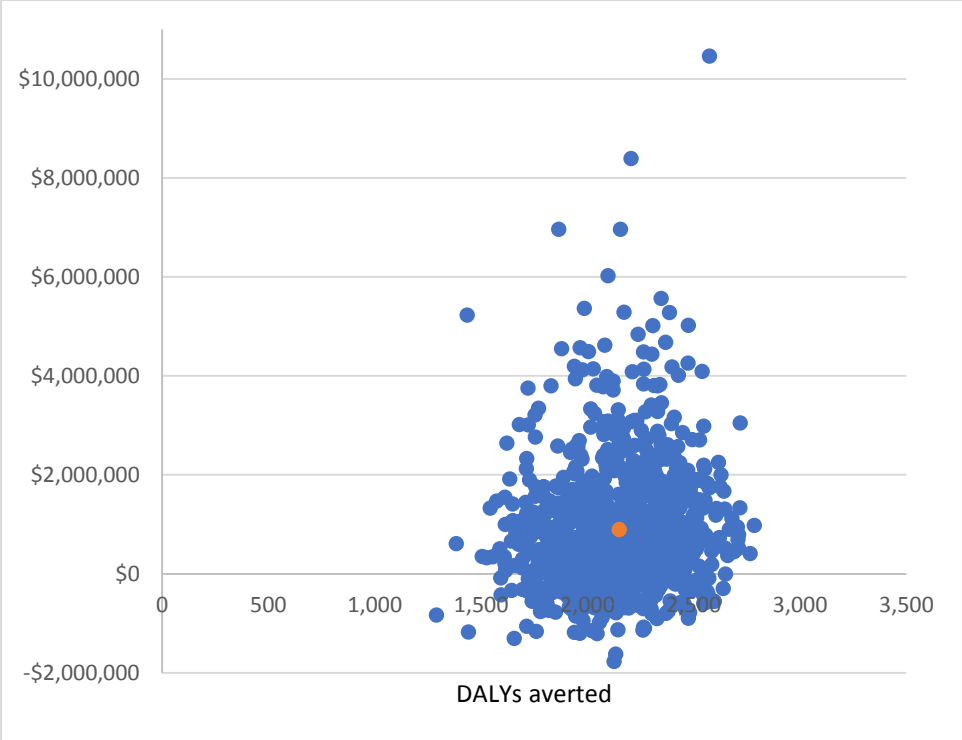
b) Zambia



c) Ethiopia



d) Lesotho



e) South Africa

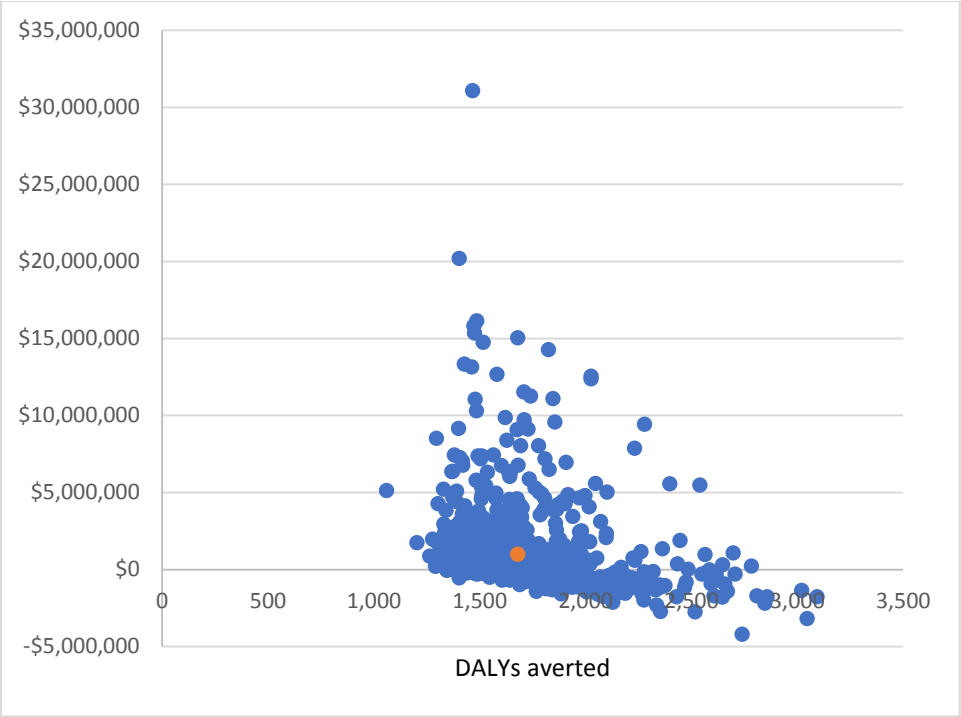
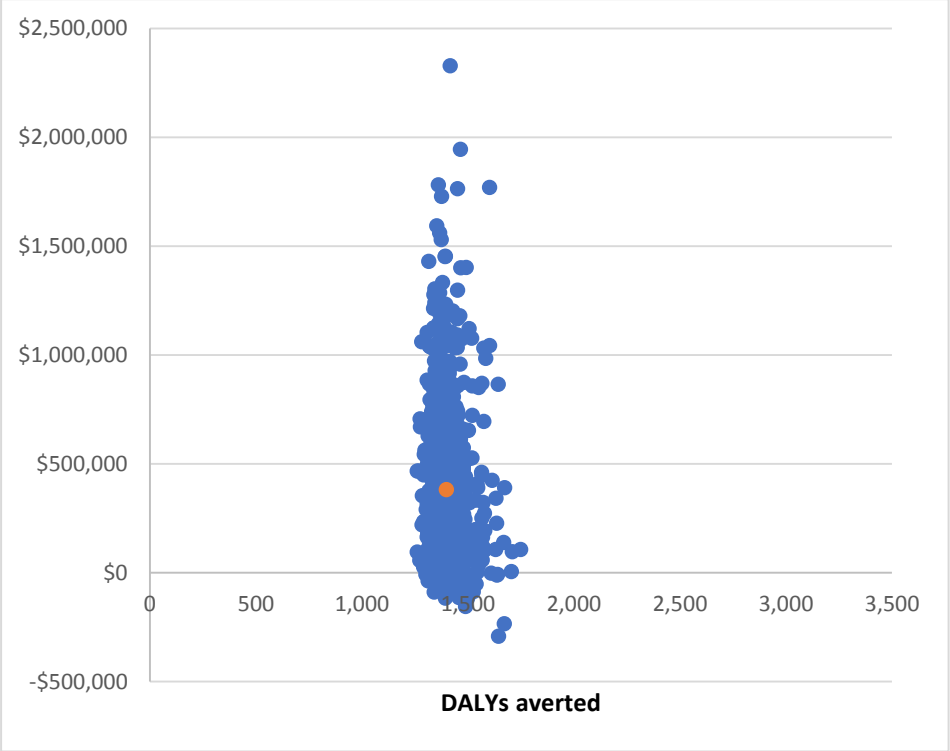
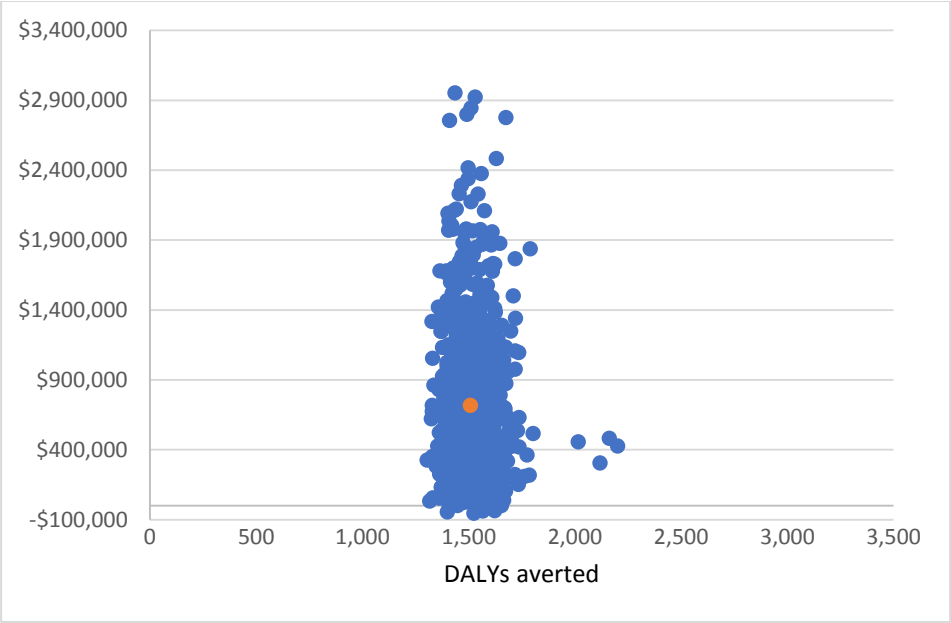


Figure S10. Cost-effectiveness planes: Multi-sectoral perspective

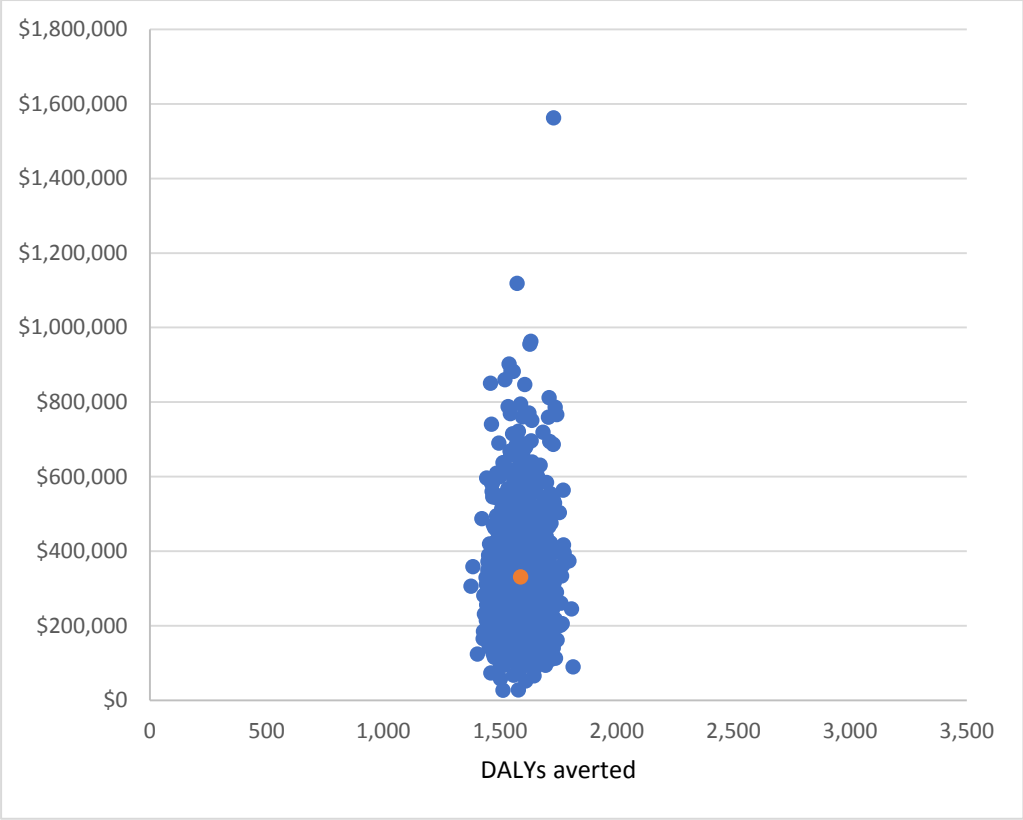
a) Tanzania



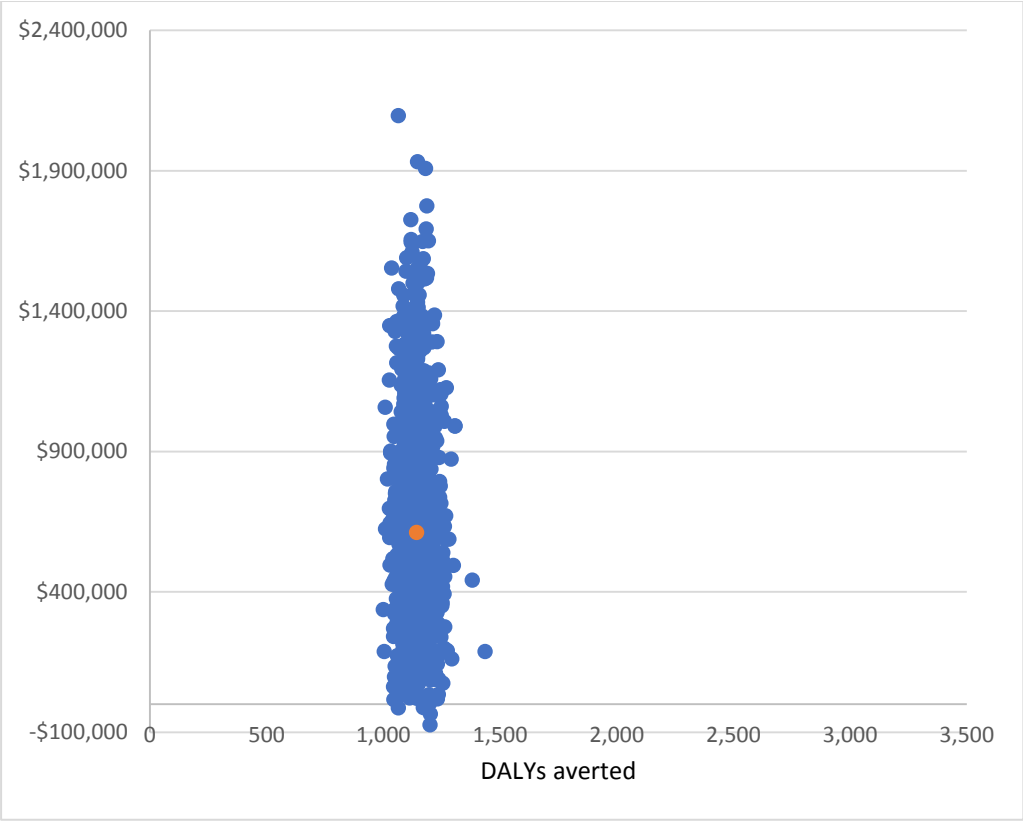
b) Zambia



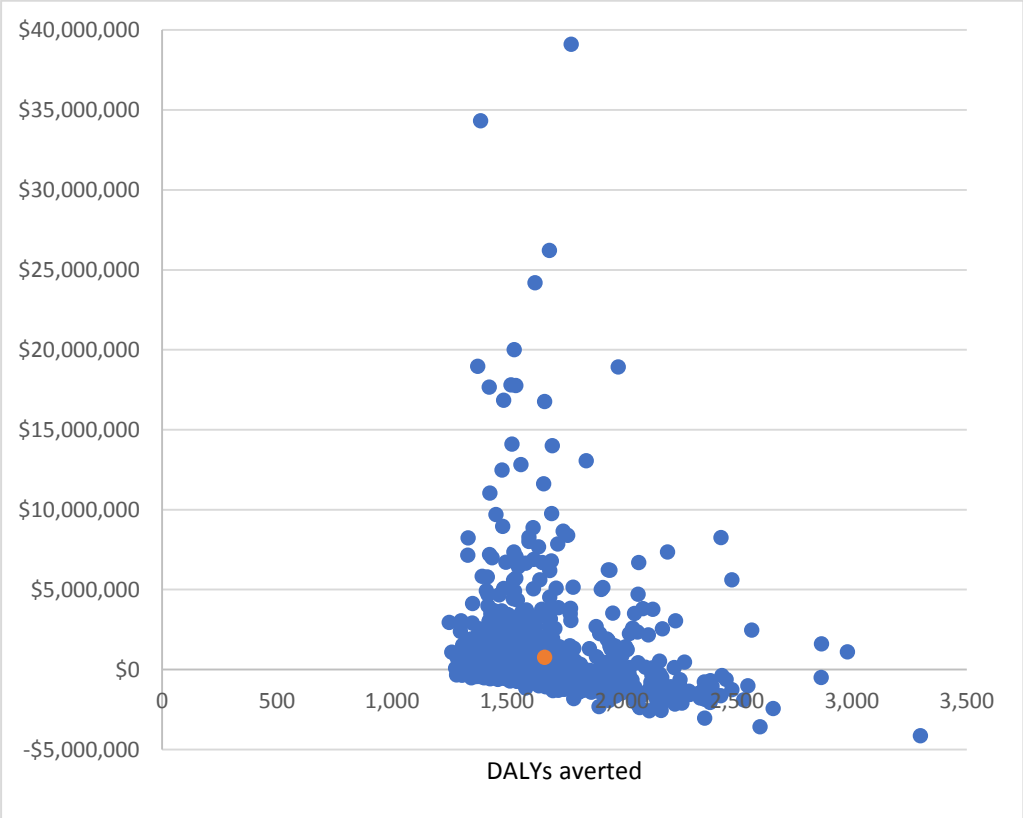
c) Ethiopia



d) Lesotho



e) South Africa



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