




Evaluation of the use of modelling in resource allocation decisions for HIV and TB

Anna L Bowring ¹, Debra ten Brink,¹ Rowan Martin-Hughes,¹ Nicole Fraser-Hurt ², Nejma Cheikh,² Nick Scott ¹

To cite: Bowring AL, ten Brink D, Martin-Hughes R, *et al*. Evaluation of the use of modelling in resource allocation decisions for HIV and TB. *BMJ Glob Health* 2024;**9**:e012418. doi:10.1136/bmjgh-2023-012418

Handling editor Seye Abimbola

► Additional supplemental material is published online only. To view, please visit the journal online (<http://dx.doi.org/10.1136/bmjgh-2023-012418>).

Received 27 March 2023
Accepted 25 November 2023



© Author(s) (or their employer(s)) 2024. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

¹Burnet Institute, Melbourne, Victoria, Australia

²World Bank, Washington, DC, USA

Correspondence to

Dr Anna L Bowring;
anna.bowring@burnet.edu.au

ABSTRACT

Introduction Globally, resources for health spending, including HIV and tuberculosis (TB), are constrained, and a substantial gap exists between spending and estimated needs. Optima is an allocative efficiency modelling tool that has been used since 2010 in over 50 settings to generate evidence for country-level HIV and TB resource allocation decisions. This evaluation assessed the utilisation of modelling to inform financing priorities from the perspective of country stakeholders and their international partners.

Methods In October to December 2021, the World Bank and Burnet Institute led 16 semi-structured small-group virtual interviews with 54 representatives from national governments and international health and funding organisations. Interviews probed participants' roles and satisfaction with Optima analyses and how model findings have had been used and impacted resource allocation. Interviewed stakeholders represented nine countries and 11 different disease programme-country contexts with prior Optima modelling analyses. Interview notes were thematically analysed to assess factors influencing the utilisation of modelling evidence in health policy and outcomes.

Results Common influences on utilisation of Optima findings encompassed the perceived validity of findings, health system financing mechanisms, the extent of stakeholder participation in the modelling process—including engagement of funding organisations, sociopolitical context and timeliness of the analysis. Using workshops can facilitate effective stakeholder engagement and collaboration. Model findings were often used conceptually to localise global evidence and facilitate discussion. Secondary outputs included informing strategic and financial planning, funding advocacy, grant proposals and influencing investment shifts.

Conclusion Allocative efficiency modelling has supported evidence-informed decision-making in numerous contexts and enhanced the conceptual and practical understanding of allocative efficiency. Most immediately, greater involvement of country stakeholders in modelling studies and timing studies to key strategic and financial planning decisions may increase the impact on decision-making. Better consideration for integrated disease modelling, equity goals and financing constraints may improve relevance and utilisation of modelling findings.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Mathematical modelling is widely used in health planning and policy, including to support understanding of infectious disease epidemics at national and global levels. Allocative efficiency modelling tools such as Optima are used to consider the most cost-effective distribution of resources to maximise specified health gains. Many global institutions place high importance on evidence-informed policies, and there is an array of literature and conceptual frameworks describing the utilisation of research evidence in policy and resulting outcomes. However, even though resource allocation is critical to HIV and tuberculosis programme outcomes, there are limited examples of groups evaluating the utilisation of modelling evidence to inform resource allocation.

WHAT THIS STUDY ADDS

⇒ Factors influencing modelling utilisation broadly reflected those for other research types, but findings provided more detail on influences for resource allocation policy decisions. This included the role of international funding organisations, the importance of flexible financing decisions and the need for models to better align to country needs and decision-making processes, such as through integrated disease modelling. The role and means of stakeholder engagement was highlighted, and using workshops can facilitate effective collaboration and communication between modellers and stakeholders and empower relevant stakeholders to interpret and apply modelling evidence.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ These findings may support modelling groups, sponsors and stakeholders to collaborate, implement and apply modelling effectively to decision-making for resource allocation. This study highlights opportunities to strengthen the local relevance, acceptance and utility of such analyses for better prioritised spending and ultimately to contribute to improved health outcomes.

INTRODUCTION

Although countries have made critical gains in reaching global targets towards HIV and tuberculosis (TB) elimination,¹ closing the remaining gap in prevention and treatment

targets will require strategic investment.^{2 3} As international HIV investment becomes increasingly constrained, countries are shifting to internal resources to fund their HIV responses. In low-income and middle-income countries, the domestic share of HIV funding has increased from 51% in 2010 to 61% in 2020, and global funds available for HIV have been decreasing since 2017.⁴ Similarly for TB, financing gaps to meet end-TB targets have widened since 2016, particularly among low-income and middle-income countries.^{2 5 6} Shrinking budget envelopes mean that governments need to make challenging decisions on HIV and TB investments amidst competing health and social priorities.

Mathematical modelling has been widely used to project epidemics at national and global levels, with models such as the Spectrum suite used to produce HIV epidemiological estimates to guide national policy and planning.⁷ Mathematical modelling is also recognised as an important tool when there are gaps in empirical data, or to compare the potential impact of different intervention, policy or funding scenarios. The use of mathematical modelling to guide health policy decisions for infectious diseases has burgeoned in recent years.^{8 9} As well as projecting epidemics under different intervention scenarios, some models can be used to inform financial resource allocation.

Optima HIV and TB are dynamic, compartmental population-based models of disease transmission and progression for HIV and TB, respectively, integrated with an economic and programme analysis framework to assess allocative efficiency. The models apply a mathematical algorithm to estimate the most cost-effective allocation of resources across disease-specific interventions to maximise progress towards specific objectives, such as reduction of new HIV-infections and HIV-related deaths or country-defined targets.¹⁰⁻¹² The models estimate the projected impact of different funding allocations on epidemic outcomes in comparison to outcomes if current spending patterns were maintained. The underlying epidemiology in each model application is calibrated to align with official reported estimates where they are available, such as those produced through Spectrum, and model outputs are validated with in-country stakeholders. Analyses are completed in partnership with national stakeholders from Ministries of Health and national disease programmes and coordinating or funding agencies. The technical modelling team provides training of varying intensity to partnering stakeholders on using and interpreting the Optima models.^{13 14} Optima HIV and TB models have been applied in over 50 countries since 2010 and 2016, respectively, in collaboration with the World Bank, international and country partners. However, it has not yet been qualitatively evaluated how these models have influenced policy or financing.

Optima modelling studies produce research and economic evidence with the objective to inform health policy and financial decision-making.¹⁵ The importance of evidence-informed policy has been highlighted by

international bodies and institutions such as the WHO, emerging from the paradigm of 'evidence-based medicine'.¹⁶⁻¹⁹ In practice, evidence-based policy is difficult to accomplish and often policy does not reflect the available evidence.^{16 18} More realistic terminology considers evidence-informed policy, which moves away from assumptions of rational and linear decision-making and acknowledges that policy is developed in complex systems influenced by judgement, values and social, political and economic factors.¹⁵⁻¹⁷ A broad array of evaluation studies and conceptual frameworks, reviewed elsewhere, describe the utilisation and impacts of research evidence on health policy.¹⁸⁻²² Specific to modelling, examples include antiretroviral treatment guidelines being informed through modelling evidence and more recently, the use of modelling in the construction and adoption of elimination targets.^{23 24}

Improved targeting of resources based on need and impact can lead to substantial reductions in epidemic burden for HIV and TB.^{11 25} Despite the widespread use of mathematical modelling in health planning and policy, there are limited evaluations of how modelling findings and recommendations are adopted by countries into policy and programming, particularly in terms of resource allocation.²⁶⁻²⁹ This evaluation sought to assess the outcomes and factors influencing utilisation of modelling research in health policy and practice from the perspective of the major consumers of Optima HIV and TB modelling: country stakeholders and their international partners. These findings will provide constructive insights on ways to improve the conduct and management of modelling research to maximise the relevance, perceived usefulness and application of modelling results for setting health financing priorities.

METHODS

Study overview

This study draws on qualitative data collected as part of an internal feedback and quality assurance exercise of Optima HIV and TB applications. In October to December 2021, the World Bank and Burnet Institute invited key stakeholders from countries involved in prior Optima applications to participate in a virtual interview to discuss their experiences and satisfaction with the modelling and engagement processes, how the model findings and recommendations had been used in country, and perceptions on the usefulness and impact of Optima analysis for supporting decision-making and addressing evidence gaps.

Participant selection and description

Study participants were purposively sampled from country stakeholders and international partner organisations who have participated in or funded Optima HIV and TB analyses. The research team compiled a list of all previous Optima HIV and TB analyses from 2012 to 2019. Analyses conducted after 2019 were excluded

Table 1 Overview of study participants

Country/region	Disease focus	Number of interviews	Number and type of interview participants	Language of interview(s)	
Belarus	TB	2	5	NTP	English/Russian*
	HIV	1	4	UNAIDS, GF	English/Russian*
Botswana	HIV	1	3	NAP	English
Eastern Europe and Central Asia	HIV	1	1	GF	English
Eswatini	HIV	1	5	NAP	English
Kyrgyzstan	HIV	1	2	NAP, UNAIDS	English/Russian*
Latin American and Caribbean	HIV	1	1	GF	English
Malawi	HIV	2	1	MOH †	English
			1	GF	English
	TB	1	4	NTP	English
Mozambique	TB	1	5	MOH	English/Portuguese*
Peru	TB	1	8	MOH	Spanish ‡
Ukraine	HIV	2	2	MOH	English/Ukrainian*
			2	UNAIDS	English
Zimbabwe	HIV	1	10	MOH, NAP	English

*Interpreter present.
 †Technical consultant.
 ‡Facilitated in Spanish and notes translated.
 GF, Global Fund; MOH, Ministry of Health; NAP, National AIDS Programme; NTP, National TB Programme (or local equivalent); TB, tuberculosis .

due to insufficient time elapsed to evaluate quantitative impact (supplementary analysis not covered in the present findings). The research team contacted stakeholders from 18 countries via email, purposively selected based on the above criteria and to maximise geographical region representation, to invite them to participate in an interview. Up to three email contact attempts were made to invite participation, which was voluntary. Where possible, representatives from a variety of organisations that had been involved in the modelling exercises were invited and included, such as National AIDS Programmes (NAP), National TB Programmes (NTP), Ministry of Health (MOH), the Global Fund and the Joint United Nations Programme on HIV/AIDS (UNAIDS).

Overall 54 country and international stakeholders working in 9 countries agreed to participate in the qualitative assessment, representing a total of 11 country-disease contexts: 5 countries with an HIV analysis, 2 countries with a TB analysis and 2 countries in which both HIV and TB analyses were conducted (table 1). Two regional representatives were interviewed for their perspectives on multiple Optima HIV analyses conducted in their respective regions.

Within their organisations, participants' positions included those relating to: strategic information, data analysts, monitoring and evaluation; programme officers and specialists; programme directors; planning and coordination; finance specialists; and specific to international health and funding organisations, country managers. For the purpose of reporting confidentiality, study

participants are only identified by stakeholder group (CS: country stakeholder; IFHO: international funding or health organisation representative).

Data collection procedures

Overall, 16 in-depth small group interviews were held with 45 country stakeholders and 9 international funding or health organisation representatives (table 1). Burnet Institute and World Bank representatives facilitated virtual interviews via the videoconferencing software Zoom using a semi-structured interview guide (see online supplemental material). This provided flexibility to explore new themes as they arose while probing participants' roles and satisfaction with Optima analyses and how model findings have had been used in country and impacted funding. Each interview involved 1–10 participants and went for 45–60 min. If more key stakeholders were identified or were unavailable in the first interview, a second interview was conducted. Interviews were led in English with the exception of one led in Spanish, with interpretation for other languages where required. Interviews were audio recorded with verbal consent from participants.

Data analysis

Qualitative data consisted of detailed and analytical notes taken during all interviews in English supplemented by partial transcriptions. Interview recordings were partially transcribed focusing on informational content except in three interviews impacted by recording error. Qualitative data were managed and coded using Microsoft Excel. The

framework method was used, applying an inductive approach to coding to allow for themes reflecting locally-situated and unexpected responses rather than embedding the coding in any single conceptual framework.³⁰ Following familiarisation with notes and audio recordings, the lead author used open coding to classify all data. Codes were grouped into broader categories based on inter-related ideas and concepts concerning either the utilisation or outcomes of Optima research, forming an analytical framework. The framework was iteratively refined in the process of comparing and contrasting emerging concepts, reducing the data for clarity and until no new codes emerged. The resulting framework was applied onto existing categories and codes, charting a matrix of data by respondent group and codes. The interpretation process involved assessing the thematic data for characteristics, patterns and differences, exploring relationships between research utilisation and impact and interrogating the analytical framework against established theoretical frameworks of research use and impact.¹⁸ Outcomes of Optima research were applied to an existing framework categorising primary outputs (outcomes improving knowledge and benefiting future research), secondary outputs (reflection of modelling evidence in planning, decisions and advocacy and improved allocation of resources) and final outcomes (gains in cost-efficiency or funding).¹⁸

The coding and analysis were led by the lead author with input and review of the analytical framework from other authors during regular meetings. The results presented in this manuscript primarily focus on the factors influencing modelling evidence being used in health policy and practice.

Public involvement

Participants were not involved in the evaluation design or conduct but participated in the implementation of the original Optima modelling studies, including priority setting, data collation, result validation and interpretation. A draft version of this manuscript was disseminated to all study participants prior to submission with an opportunity to comment on how their experiences were represented or opt out of having their data included in the published manuscript. No participants objected to publication. The evaluation findings are also being circulated to participating groups as country case studies and a technical report. The findings of this evaluation will inform public involvement in future Optima modelling studies.

RESULTS

Factors influencing research use

Five major themes were identified that act as facilitators or barriers to using modelling findings in policy and financing decisions (table 2).

Perceived validity of findings

Perceived validity of findings was influenced by accordance of findings with expectations, organisational beliefs and alternative evidence. Model outcomes that confirmed existing assumptions or other evidence were used to

justify spending resources and strengthen funding applications:

There were no surprising findings, but it validates the intuitive thinking. (IFHO)

Where **findings corroborated global guidance** or institutional beliefs, Optima added to a local evidence base and increased motivation for using the findings in resource allocation.

The finding of the Optima exercise has strengthened that thinking and that expectation. (CS4)

For instance, in one country Optima findings were actively used in discussion with government bodies to scale-up opioid substitution therapy (OST), helping to overcome legislative barriers to OST prescription and gain multidepartmental support for OST. Despite there being considerable existing evidence for interventions such as OST, stakeholders valued the ability of Optima to **contextualise global evidence** to the local setting.

Conversely, in some settings where **results challenged expectations or beliefs**, the modelling evidence was discounted or not considered for financial decision-making, such as an example where voluntary medical male circumcision (VMMC) was not prioritised. In certain cases respondents communicated **dissatisfaction with the choice or handling of data** used in the model, despite commonly reporting involvement in data collation. In the above example, stakeholders had queried the VMMC programme cost data used in the model. In one setting with pronounced **uncertainty** on population size estimates, stakeholders believed that the proportion of new HIV infections among people who inject drugs (PWID) had been overestimated in the Optima model and thus resisted implementing recommendations to scale-up PWID prevention interventions.

The last two rounds surfaced a negative factor for [country]: 50 percent of the new HIV cases come from IDUs [people who inject drugs], which in reality is not the case. We did send our remarks emphasizing that we do not have such a high rate among IDUs. (CS8)

Perceived validity was also compromised in select examples when there were discrepancies between Optima HIV and epidemiological projections from other HIV epidemiological models used for annual planning and forecasting.

Diverse stakeholders emphasised that the policy environment is increasingly structured around cross-cutting programmes, including structural interventions and integrated disease programmes. Respondents portrayed that reflecting these elements in modelling by **aligning analyses to country targets and priorities** would facilitate broader utilisation in policy decisions.

In some settings respondents conveyed that there was a general **scepticism of modelling** among some personnel involved or key decision-makers due to perceived subjectivity and potential for biases during model calibration. This was not unique to Optima but had led to some

Table 2 Facilitators and barriers of using modelling evidence in policy identified in the evaluation

Facilitator	Facilitator	Either facilitator or barrier	Barrier
Perceived validity of findings	<ul style="list-style-type: none"> ▶ Awareness and understanding of Optima. ▶ Familiarity with mathematical modelling. ▶ Findings corroborated global guidance. ▶ Modelling contextualises global literature and evidence. ▶ Extended training. 	<ul style="list-style-type: none"> ▶ Local capacity. ▶ Alignment with country targets and priorities. ▶ Data availability and quality. 	<ul style="list-style-type: none"> ▶ Scepticism of modelling. ▶ Uncertainty in underlying data. ▶ Dissatisfaction with choice or handling of data. ▶ Results challenged expectations or beliefs. ▶ Consequences for health and social equity.
Stakeholder engagement	<ul style="list-style-type: none"> ▶ Wide range of stakeholders. ▶ Multisectoral engagement. ▶ Key international funding organisations consulted throughout modelling process. ▶ Local ownership. ▶ Joint planning. ▶ Opportunities for dialogue. ▶ Interactive process. ▶ Alignment with country needs and priorities. ▶ Previous involvement. ▶ Follow-up ▶ Tailored and clear dissemination products. 	<ul style="list-style-type: none"> ▶ Engagement with policy and programme leads. 	<ul style="list-style-type: none"> ▶ Optima involvement driven by international funding organisations. ▶ Insufficient opportunity for feedback. ▶ Narrow participation. ▶ Inadequate dissemination.
Timing and opportunity	<ul style="list-style-type: none"> ▶ Completed prior to key grant applications. ▶ Sufficient time allocated. 	<ul style="list-style-type: none"> ▶ Data availability at time of analysis. ▶ Integration with other modelling and costing exercises. 	<ul style="list-style-type: none"> ▶ Finalised too late to inform key strategy or funding organisation decisions. ▶ Other priorities competing for time and resources.
Health system financing	<ul style="list-style-type: none"> ▶ Health system reform. ▶ Mechanisms to transfer funds between activities and funding streams. 	<ul style="list-style-type: none"> ▶ Influence on budgeting decisions. ▶ Funder preferences and priorities. 	<ul style="list-style-type: none"> ▶ Historical allocation patterns. ▶ Line-item budget systems. ▶ Fragmented funding streams
Sociopolitical context	<ul style="list-style-type: none"> ▶ Political will. 		<ul style="list-style-type: none"> ▶ Sociopolitical unrest. ▶ COVID-19 pandemic and response.

stakeholders being critical of modelling evidence. One country representative explained that evidence generated through modelling was perceived as inferior to empirical data derived from programmes or intervention studies.

When they see the back of it and appreciate that they can play with the figures, then it becomes more [of a] political instrument rather than [an] epidemiological instrument. (IFHO)

Participants described resistance to findings among some stakeholders when a specific population group would be disadvantaged by implementing Optima recommendations due to **consequences for health and social equity**, including health impacts outside of HIV/TB, if funding were reduced.

We faced some challenges and resistance while reallocating those funds, specifically on the side of civil societies and NGOs because due to the Optima results, we had to

taper off funding from one community and groups towards the others. (CS2)

Respondents discussed a few means to strengthen perceived validity of Optima and modelling processes. Most eminently, **extended training** and building local capacity to use Optima were portrayed as a key route to developing local ownership and building local skills and capacity to support, interpret and independently use modelling studies. The training provided from Optima was appreciated in many settings:

In terms of training, I think it was useful. For each country group there was a representative delegated by your institution... It was quite interesting and efficient. (CS8)

However, respondents from one country conveyed that no training had been received, and respondents from multiple countries suggested that more training would have been useful, particularly for technical leads.

Need to increase the ownership of Optima here locally through a greater amount of trainings. Yes, we have gone through the five day long workshop, but it was quite intensive yet still not enough. We need more hands-on training later on. Optima math modeling is quite sophisticated, and not something you will get fully in five days. And what we need essentially here is the experts or resources who would be capable of using Optima on their own, to the extent possible. So more training would be required. (CS2)

Funding organisation representatives favoured in-person workshops for training and modelling, suggesting they offered a more immersive experience and facilitated meaningful involvement and dialogue.

Beyond training, **familiarity with Optima and allocative efficiency** was achieved through involvement in repeat Optima analyses or other HIV investment case projects and facilitated more meaningful engagement with the processes, including the critical assessment of data inputs and findings and enabled greater ownership.

Stakeholder engagement

The extent, timing and type of stakeholder engagement was a major theme influencing the uptake of modelling findings. International representatives perceived that effective engagement with in-country stakeholders, and particularly the MOH, was integral to fostering **local ownership** of Optima products and required concerted effort and time to achieve.

This component of ownership is probably the hardest, and it's the one that was emphasized a lot. It started with a letter to the Ministry of Health from us. And then it was, when you own it, you designate that this is your report. And then they validate the reports, and so on. And some cases it took quite a long time to validate the final reports, but we got to it... Despite all of the other priorities that were running. So in that sense, I don't think that any country will tell you 'they don't know', 'we didn't do it, it's something that [IFHO] did'. It's not the [IFHO]—they did it. (IFHO)

Although representatives from the NAP, NTP and/or MOH usually led country involvement in Optima, country respondents generally appreciated engagement of a **wide range of stakeholders**, spanning technical and policymaking roles and **multisectoral** representation from non-governmental organisations and civil society organisations (CSO), funding partners and UNAIDS. Representatives from one country emphasised the importance of discussing findings with ministries outside of health to gain broader support for interventions such as OST and to influence national strategy.

The joint oversight committee meeting is the one that is critical because the stakeholders, or the members rather, are the CEOs and country directors of all of the stakeholders in the HIV/AIDS response. And therefore those are the decision makers of allocation of funds. (CS1)

It would be beneficial to include someone from civil society in this taskforce. If excluded, they might think the government is hiding something or has some sort of hidden

agenda. We will gain more support and understanding from them if that person will be included. (CS2)

In numerous settings, effective **joint planning** between country partners and the Optima team supported **alignment with country needs** and the actioning of study recommendations.

It was the NTP that proposed the modeling exercise should be done at district level. (CS4)

It's not that we say 'you should invest more in treatment because we are the [IFHO]; We say, 'we together ran the analysis, here is the science behind it. This is how much money we need to hit the 90-90-90...It helps to have, you know, 'we've done this together, this is what the data says, so this is probably where we should move'. (IFHO)

However, there were differing views on whether **policy and programme leads**, including government officials, should be involved earlier and throughout the analysis to promote ownership of findings, or whether it was effective to limit engagement to stages such as defining national policy questions and dissemination. In some settings international funding representatives emphasised that they intentionally focused participation on monitoring and evaluation (M&E) personnel to promote Optima as a data-driven technical exercise and avoid findings being perceived as political.

We sold it as a very technical exercise. And we involved people from the M&E departments. There were no decision makers, just the people who do the data, the M&E. So the result was it was a very helpful exercise... (IFHO)

In contrast, stakeholders from one country felt that limiting involvement of relevant international funding entities to dissemination may have inhibited the appreciation and uptake of findings, suggesting **earlier engagement** may have been more effective.

They were hearing [of Optima analysis] for the first time and being on the tail end of it. Which might have been a little too much to chew at one sitting...It would work better if we get them through the mill earlier on before we get to the results. (CS1)

Participants valued meaningful **opportunities for dialogue**, and in isolated cases respondents recalled insufficient opportunity to provide feedback, thus limiting the perceived validity and subsequent application of findings.

We were not able to follow through the whole process because we were not in a position to give feedback to our principles [country leads]. (CS3)

In one setting, respondents attributed the lack of ownership to minimal follow-up, discussion and influence of Optima results on policy.

It's an important factor, that the [name of institution], which was the key institution, to own the results of this analysis-modeling exercise. The [Institution] did not really promote Optima. Has not brought up Optima recommendations in discussions about the Global Fund Proposal. Or the PEPFAR funding. Or the National AIDS Strategy.

I still think they have not released this document as final. (IFHO)

Timing and opportunity

Timeliness of Optima analyses influenced research utilisation by impacting availability of data to parameterise models and opportunity to **inform key strategy or funding decisions**. In some cases, strategic planning was successfully informed by preliminary findings.

The exercise was still being done during the strategic plan development and also the NFM [New Funding Mechanism] grant making. I think this was the major time when there has been key decision making and resource allocation. Since we had some preliminary output from Optima, I think those recommendations were also being considered and incorporated in those kind of exercises. (CS4)

Both country and funding organisation representatives spoke about the importance of factoring in **sufficient time** for preparation, country engagement and data collation and to anticipate timing of most recent epidemiological or financial studies. Representatives from one country expressed poor timing of analytical activities due to **inadequate integration of various modelling and costing exercises**. This led to a duplication of effort to track resources and collate data, such as for National AIDS Spending Assessments, National Health Accounts, Optima and Spectrum.

Competing demands at the time of Optima analyses and busy agendas were constraints on stakeholder engagement. In one example, the Optima application happened simultaneously with the development of the M&E framework for the new National Strategic Plan, thus limiting staff availability to support the Optima analysis.

In the context of [country name] ...there are lots of conflicting priorities. ... The concept of efficiency was not high on the agenda. The other problems they are facing, in their view, are more important. No human capacity or time to focus. (IFHO)

In some cases, stakeholders recognised that competing priorities coupled with limited resources increased the perceived value and application of allocative efficiency analyses.

The issue of allocative efficiency always remains a priority in terms of our response because we don't have adequate resources and we also do have now quite a number of competing priorities. (CS3)

Health system financing mechanisms

Respondents from several settings identified that **funder preferences** had a bigger influence on resource allocation than Optima findings. The two were not necessarily exclusionary, and funder support may have reinforced the scale-up of interventions such as HIV self-testing, which was prioritised in several Optima analyses. Elsewhere respondents conveyed that pre-exposure prophylaxis was being scaled-up, despite this not being supported

by model findings, due to pre-established funding and government priorities.

Country representatives and funding organisation representatives both relayed that budgets tended to favour **historical allocation patterns**, which limited utilisation of research findings in policy and financing decisions in some settings.

Funding for subsequent years would usually be predominantly based on the previous year. So it's more of a recurrent budget and budget proportions, not necessarily guided by evidence of impact. (CS1)

In some settings budget reallocations were constrained by the health system financing model. Systems that used **line-item budgets** (Line-item payment systems define the total amount to be financed to a hospital or other organisation based on the expected costs of clinical and non-clinical staff, equipment, medicines, utilities and maintenance, which are determined based on expenditure in the previous year)³¹ to finance inpatient services lacked the flexibility and incentive to transition to ambulatory, decentralised care models, even when Optima findings demonstrated alternatives to be more cost-effective and efficient. Without changing how health services are funded at a structural level, adopting these changes would lead to reductions in hospital funding in subsequent years. In these cases, the system lacked appropriate **mechanisms to transfer funds**, such that savings could not be reinvested in alternative activities nor for comparable care outside of the hospital setting.

The number of beds have decreased, but this does not mean that they release the funds ... for other activities. (CS5)

Fragmented funding of epidemic responses also posed challenges to redistribute either existing funding or cost-savings through implementation efficiencies. Respondents from several settings spoke of difficulties in transferring cost-savings from general population HIV testing programmes to key population prevention and testing due to different sources of programme budgets.

Of course, for [country name] Government it is easier to fund HIV treatment and expenditures related to treatment, care and support for HIV positive people [sic]. The Government covers around 80 per cent of such expenditures...In terms of the prevention programs ... the cost sharing in this case is the opposite: 80 per cent will come from Global Fund. (CS7)

In one case this meant that while the state budget increased commitments for key population prevention in line with Optima recommendations, eventually these funds were not disbursed due to the complexity in actualising resource reallocation. Subsequently, **health system reform** was identified as a potential enabler of resource allocation in line with modelling recommendations.

Respondents from one setting discussed that social contracting was being introduced to reduce the dependency on international funding, promote sustainability

and improve the efficiency and quality of care. This enabled public health centres to purchase HIV prevention services through non-government and CSOs. The respondent felt that making the government the main recipient of international funding gave them more power to advocate to local governments and increase funding for key population programmes through social contracting, in line with modelling recommendations. They described this as a lengthy process taking place over 2–3 years which eventually enabled better adoption of allocative efficiency findings.

So, [local governments] begin to see the benefits of these expenditures now as well as the purpose of it. Thus it is much easier to convince them now that funding for these areas should be increased. So, the role of the main recipient as a main driving force in advocating state social contracting is very strong. (CS7)

Optima commonly engages most closely with the NAP and NTP for HIV and TB studies, respectively. Some respondents referred to these parties having **limited influence on budget** decision-making. Their actions were constrained to making recommendations to the relevant government structure, but this was insufficient to enable the application of Optima findings to resource allocation in some settings.

The NTP is not the owner of the government funds. It has limited influence on how the funds are allocated. (CS5)

Country teams often found it difficult to differentiate direct from **indirect spending** (eg, management costs and overheads). The latter is generally considered a fixed expense in Optima analyses, but some respondents reported a need to better understand indirect spending, such as administrative costs and supply chain management, to inform resource allocation.

The performance of a program depends on various factors, which I believe need to be included in future modeling to bring robust results...For instance, we have a shortage of human resources – it's one of the determinants of the performance. (CS6)

Sociopolitical context

Respondents considered that **political will** was important when findings concerned key population groups or migrants, which were politically sensitive in some contexts. In settings where related behaviours are criminalised or these groups are not prioritised in existing resource allocation, Optima findings were more likely to face resistance from policymakers, particularly outside of the NAP or NTP or at a subnational level. This was particularly pertinent in settings in the process of transitioning from international to domestic spending.

A governor in a region may have never heard before how MSM [men who have sex with men] are influencing pandemics and now he is told that funds need to be allocated for condoms for this group, for lubricants. Usually, these things come as a shock to local government. (CS7)

Despite the expected resistance in these settings, funders perceived that Optima supported advocacy by providing objective rationale for prevention programmes for key populations. Optima provides an opportunity to 'put the science before the politics' (IFHO), and in this way has the potential to depoliticise resource allocation.

External factors such as **sociopolitical unrest** also impacted the influence of Optima findings on resource allocation. In one setting, conflict and the existence of autonomous regions meant that subnational HIV programmes and services are not controlled or funded by the government, and thus not influenced by government resource reallocations. The **COVID-19 pandemic** placed strain on healthcare resources and budgets, necessitating diversion of funds from other health programmes: 'Every free cent was reallocated to COVID' (CS8). In some settings, respondents reported increases in service costs due to COVID-19, limiting the relevance of prior allocative efficiency analyses.

Outcomes of Optima applications

Country stakeholders and funding organisation representatives conveyed that Optima HIV and TB analyses have led to a range of outcomes which can be broadly grouped as primary outputs, secondary outputs and final outcomes ([figure 1](#)).¹⁸

Although final outcomes have greater significance to cost-effective programming and ability to impact epidemic measures, many respondents also acknowledged the value of the more immediate primary outputs such as generating internal dialogue and strategic thinking on programmes, priority populations and data gaps.

The exchange of the results of this modeling – what works, what doesn't work, what data we have...catalyzes internal discussions about the quality of data and the completeness of data. (IFHO)

The most common application of Optima HIV and TB analyses reported by interview respondents was to inform grant proposals and strategy documents. The timing of Optima analyses was often tied to Global Fund funding requests, and Global Fund grants were most frequently cited as having been informed by Optima. Specifically, respondents referred to using Optima findings to help set and review targets, select high-impact and cost-effective activities and plan budgets. This was corroborated in publicly available grant proposals. Some respondents referred to using Optima findings to support advocacy for new investments, such as changes to modalities for testing and treatment delivery.

As a country I think we did benefit in terms of the exercise because it opened our eyes in terms of the different programs where we need to prioritize as a country; where we can spend less and get more from. (CS9)

In four settings Optima-informed advocacy led to mobilisation of additional funding.

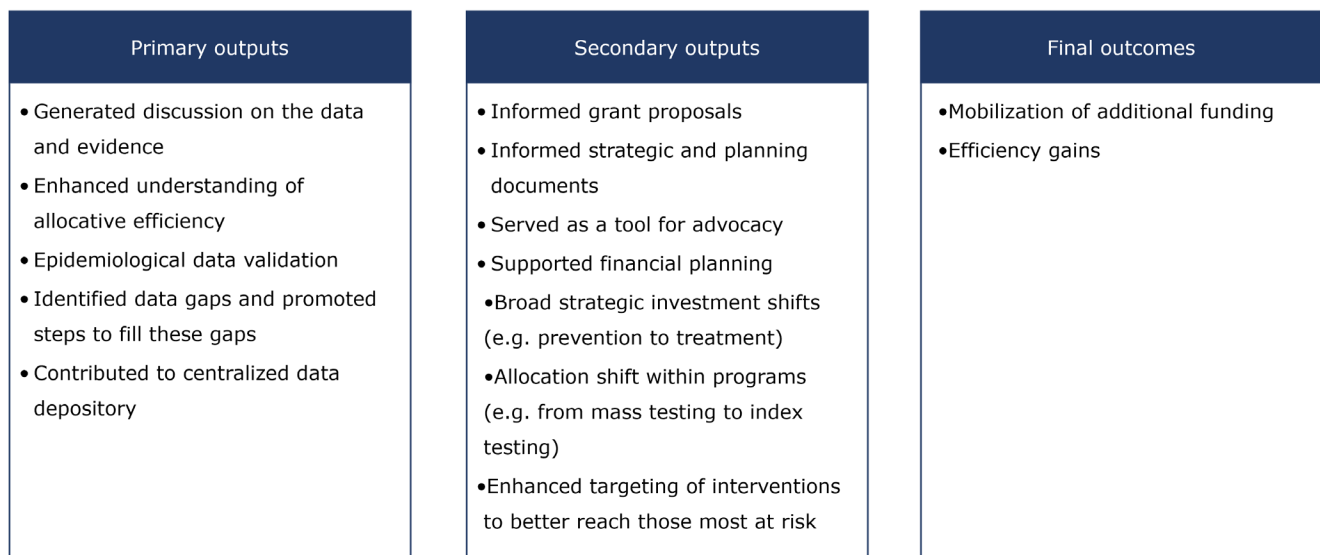


Figure 1 Overview of outcomes reported from involvement in Optima HIV and tuberculosis analyses.

One of [the Optima recommendations] was to expand the coverage of community outreach and preventive treatment among high risk and vulnerable populations. It indirectly oriented us to advocate for money. ... so eventually that guided us to allocate more in these two particular interventions. (CS6)

A representative from an IFHO described how Optima had provided supporting evidence for ongoing advocacy efforts to reduce the price of antiretrovirals, given differential pricing made obvious through a regional Optima exercise.

Funding organisation representatives in particular considered that Optima provided an objective basis for policy advocacy, which was particularly useful when results supported increased funding for programmes not readily supported by the government agenda, such as the scale-up of OST.

The biggest breakthrough in our case was with opioid substitution therapy. In 2018 the expenditures were at US\$103k, while in 2022 they committed US\$800k with an increase to US\$825K in 2024. (CS7)

DISCUSSION

This evaluation confirmed there are a multitude of factors influencing the use of modelling to guide resource allocation for national HIV and TB programmes. Allocative efficiency modelling has a supportive role in opening dialogue around budget allocations, providing localised evidence to support planning and advocate for funding and helping policymakers visualise the benefits and consequences of different scenarios, including maintaining the status quo, to enable informed policy decisions. Facilitating stakeholder engagement and collaboration between policymakers and researchers can help to bridge modelling evidence, policy and practice for greater impact in achieving health outcomes.

Facilitators for the utilisation of modelling evidence for administrative policy decisions were perceived validity and relevance of modelling evidence, strong collaboration between country stakeholders and research staff, timeliness and appropriate dissemination of research. These were consistent with facilitators described for other forms of research evidence,^{19 21 32} as well as elements of multiple conceptual frameworks of research utilisation in policy, including the RAPID Framework and the Interfaces and Receptor Framework.^{18 22} The current findings provide practical guidance on how to apply these frameworks to modelling to strengthen multidirectional linkages between research, political and funding groups.

Interviewees described a wide spectrum of stakeholder participation in Optima analyses. Existing research prescribes stakeholder engagement as one of the key principles for effective modelling and researcher-stakeholder partnerships as a facilitator of research utilisation in policy.^{18 21 33} However, most modelling guidelines focus on technical aspects or results communication³⁴ and there is relatively less emphasis on how to work together with policy and decision-makers.³⁵ We found that using workshops can facilitate direct engagement, collaboration and effective communication between modellers and stakeholders and empower relevant stakeholders to use and interpret modelling. The timing of engagement, variety of stakeholders involved and types of contributions were all perceived as important, but there were differences in opinion on how to optimise stakeholder engagement, suggesting a need for deliberate strategic approaches. Findings also supported the value of previous involvement in modelling to build on local capacity and support local leadership in applying modelling to HIV and TB programme decision-making.¹⁸ However, high turnover of personnel in some positions may potentially be a barrier to building institutional capacity and familiarity with modelling.²¹ Where models are not

institutionalised at a national level, additional funding may be needed to support remuneration and mobilise appropriate national consultants and teams to engage in the modelling process.

The perceived validity of findings was influenced by stakeholder experience, currently held beliefs and available evidence. Although participants valued the discussion facilitated through the modelling process and outcomes, we observed that findings that contradicted stakeholders' beliefs were more likely to be rejected. This may be particularly true for programmes that are also politically polarising, such as those serving key populations. Several researchers have endorsed the idea of models as a 'boundary object' which even through disagreement or uncertainty, can promote multidirectional dialogue and exchange to support priority setting and mediate knowledge into policy decisions.^{9 29 36} Providing sufficient opportunity for diverse stakeholders to deliberate and discuss findings may help to promote dialogue and prevent disagreement from blocking evidence utilisation.^{9 21 26}

Other research has reported on modelling evidence being used symbolically to support existing decisions and strategy when model findings are consistent with stakeholder beliefs.²⁶ International funding organisations, government bodies and public health researchers may also have preconceived notions or agendas, and evidence that resonates these assumptions and priorities is more likely to influence policy.²² Although this evaluation revealed some selective use of evidence, more profoundly it showed that even when the modelling was not attributed with providing new evidence, it could validate and contextualise global empirical evidence and guidance. Subsequently, conceptual use of modelling evidence promoted acceptance and adoption of impactful evidence-informed practices.³²

Modelling was considered less credible than empirical data for informing policy decisions among select stakeholders. Although several studies recognise the importance of the type of research or evidence in affecting uptake for policy decision-making, modelling science is rarely explicitly mentioned in these texts.^{16 19 37} The evaluation findings support the work of Rhodes and Lancaster, which highlights that inherent uncertainty in modelling, use of projections and abstraction can mean they are viewed as a weaker form of evidence by some decision-makers.⁹ A review of use of modelling evidence in WHO guidelines showed that modelling-informed guidelines were considered to have lower quality of evidence than guidelines not informed by modelling evidence, although this may be biased by when modelling evidence is preferentially used.³⁸ Strengthening collaborations between researchers and country stakeholders, particularly through participatory modelling, can improve the quality of models by maximising available data to parameterise models,³⁶ and may thus help to promote confidence in modelling evidence.

Findings demonstrated higher perceived value of modelling among stakeholders when it was built around country priorities, timing of policy decision-making and the broader health system context. Consistent with other studies, we found that international funding organisations often initiate the analyses or define the modelling objectives.²⁷ Funding organisations may have a more vertical approach than national disease or health programmes,³⁹ which may limit the perceived usefulness and national uptake of findings. Both national and international stakeholders conveyed a need for modelling to support integrated disease and programme delivery, structural interventions and decisions around human resources and programme administration. By not accounting for these, disease-specific models may not fully capture operational feasibility and decision-making processes, thus undermining perceived validity.⁴⁰ Multi-disease, 'whole system' approaches which consider interactions between diseases, interventions and the health system, such as for the Thanzi La Onse model in Malawi, may enhance the relevance of modelling for local decision-making and resource allocation.^{41 42} Further modelling which considers the workforce capacity and subsequent costs will facilitate transparent and feasible estimates of providing cost-effective interventions.

Research utilisation in health policy relies on the recommendations being politically and administratively feasible.³⁷ Financing for key populations prevention programmes is frequently still provided by international funders through CSOs, while domestic funding often covers care and treatment. The evaluation findings demonstrate that this fragmented investment approach was often a barrier to redistributing funding from generalised testing and prevention to programmes focusing on key populations. Many countries dependent on external funding are graduating to domestic funding in the near future,⁴³ and some are adopting social contracting to provide tailored services to key populations through CSOs with government financing.⁴⁴ A 2021 study analysing the sustainability of CSO provided services in the Eastern European and Central Asian region found that these services, often provided by peers for those most marginalised, are slow to be financed by local governments,⁴⁵ which was also demonstrated in this analysis. The present research demonstrates that collaborative modelling exercises can support the implementation of social contracting by engaging partners in constructive dialogue and consensus building on target setting and budget allocation.⁴⁶

A number of limitations should be considered when interpreting these findings. The results may not represent the views of institutions and individuals who were non-responsive to multiple interview requests, and thus biased to settings with higher engagement in Optima processes or a more recent Optima analysis. High departmental staff turnover and secondment from HIV/TB to COVID-19 may have also impacted participation. Interviews were facilitated by the Optima research team

with the potential to introduce social desirability bias. However, the interviewers encouraged honest feedback and participants relayed both positive and negative experiences and outcomes. This evaluation focused on country stakeholders and funding organisations as key consumers of Optima research, with limited input from international health organisations. Findings may not be generalisable to other entities using modelling evidence, such as WHO. Due to technical error, verbatim quotes were not possible to include from several interviews and analysis relied on detailed notes.

In the context of increasing financial constraints on health programmes, there are opportunity costs associated with all resource allocation decisions. This evaluation demonstrates that allocative efficiency modelling has supported evidence-informed decision-making in numerous contexts, enhanced the conceptual and practical understanding of allocative efficiency and supported constructive dialogue on the data and evidence. Understanding factors that influence utilisation of modelling evidence has relevance to diverse modelling groups. Applying the lessons learnt here will support technical and in-country stakeholders to maximise epidemic impact through evidence-informed resource allocation.

Acknowledgements The Burnet Institute and the World Bank are grateful for all feedback provided by participants from country teams and from international partners and acknowledge the founding work of all personnel and collaborators who provided input on the original Optima analyses. The team extend their gratitude to Anna Roberts for support with project administration and data collection, to Jaime Nicolas Bayona Garcia, Roman Kulchynskiy and Felix Tsoy for providing translation support during interviews, and to Nisaa Wulan and Lung Vu for their contributions to the analyses and interpretation.

Contributors The evaluation was conceptualised and planned by NF-H, NC, NS, DTB and RM-H. Data collection was carried out by DTB, NF-H, AB and RM-H. Data analysis was led by AB with support from DTB. Manuscript writing was led by AB. All authors contributed to the interpretation of the data, manuscript review and editing. NS is the guarantor. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

Funding This work was funded by the World Bank, who contributed to study design, implementation, analysis, interpretation and manuscript review. The authors gratefully acknowledge the contribution to this work of the Victorian Operational Infrastructure Support Program received by the Burnet Institute.

Competing interests None declared.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not applicable.

Ethics approval The Alfred Hospital Ethics Review Committee approved the collation and analysis of the program QA data (project number: 158/22). The original quality assurance exercise was not subject to ethics review. All study participants were notified of the use of their data for extended research purposes and had the opportunity to opt out of further research.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement No data are available. Data from this evaluation is not available for sharing as per ethics agreements. Data and reports for underlying country models are published and openly available in the World Bank Open Knowledge Repository (<https://openknowledge.worldbank.org/>) and through Optima (<http://optimamodel.com/>).

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and

responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

ORCID iDs

Anna L Bowring <http://orcid.org/0000-0002-2192-9260>

Nicole Fraser-Hurt <http://orcid.org/0000-0003-3065-8666>

Nick Scott <http://orcid.org/0000-0002-9213-0798>

REFERENCES

- UNAIDS. *Global AIDS Update 2018: Miles to go*. Geneva: Joint United Nations Programme on HIV/AIDS (UNAIDS), 2018. Available: https://www.unaids.org/en/20180718_GR2018
- United Nations Department of Economic and Social Affairs. *Transforming our world: the 2030 agenda for sustainable development*. 2015.
- UNAIDS. *Understanding fast-track: accelerating action to end the AIDS epidemic by 2030*. 2015. Available: https://www.unaids.org/sites/default/files/media_asset/201506_JC2743_Understanding_FastTrack_en.pdf
- UNAIDS. *The HIV Financial Dashboard*, Available: <https://hivfinancial.unaids.org>
- World Health Organization. *Global tuberculosis report 2021*. Geneva, 2021. Available: <https://www.who.int/publications/digital/global-tuberculosis-report-2021>
- World Health Organization. *The End TB Strategy*. Geneva: WHO, 2015. Available: <https://www.who.int/teams/global-tuberculosis-programme/the-end-tb-strategy>
- Mahy M, Marsh K, Sabin K, *et al*. HIV estimates through 2018: data for decision-making. *AIDS* 2019;33:S203–11.
- Sweilheh WM. Global research activity on mathematical modeling of transmission and control of 23 selected infectious disease outbreak. *Global Health* 2022;18:4.
- Rhodes T, Lancaster K. Mathematical models as public troubles in COVID-19 infection control: following the numbers. *Health Sociol Rev* 2020;29:177–94.
- Goscé L, Abou Jaoude GJ, Kedziora DJ, *et al*. Optima TB: A tool to help Optimally allocate tuberculosis spending. *PLoS Comput Biol* 2021;17:e1009255.
- Kelly SL, Martin-Hughes R, Stuart RM, *et al*. The global OPTIMA HIV Allocative efficiency model: targeting resources in efforts to end AIDS. *Lancet HIV* 2018;5:e190–8.
- Kerr CC, Stuart RM, Gray RT, *et al*. Optima: A model for HIV epidemic analysis, program Prioritization, and resource optimization. *J Acquir Immune Defic Syndr* 2015;69:365–76.
- Optima. Optima HIV user guide and training materials, Available: <http://optimamodel.com/hiv/documents.html>
- Optima. Optima TB user guide and training materials, Available: <http://optimamodel.com/tb/documents.html>
- Bowen S, Zwi AB. "Pathways to "evidence-informed" policy and practice: a framework for action". *PLoS Med* 2005;2:e166.
- Oxman AD, Lavis JN, Lewin S, *et al*. SUPPORT tools for evidence-informed health policymaking (STP) 1: what is evidence-informed policymaking. *Health Res Policy Syst* 2009;7:S1.
- Lancaster K, Rhodes T. What prevents health policy being 'evidence-based'? new ways to think about evidence, policy and interventions in health. *Br Med Bull* 2020;135:38–49.
- Hanney SR, Gonzalez-Block MA, Buxton MJ, *et al*. The utilisation of health research in policy-making: concepts, examples and methods of assessment. *Health Res Policy Syst* 2003;1:2.
- Orton L, Lloyd-Williams F, Taylor-Robinson D, *et al*. The use of research evidence in public health decision making processes: systematic review. *PLoS One* 2011;6:e21704.
- Newson R, King L, Rychetnik L, *et al*. Looking both ways: a review of methods for assessing research impacts on policy and the policy utilisation of research. *Health Res Policy Syst* 2018;16:54.
- Oliver K, Innvar S, Lorenc T, *et al*. A systematic review of barriers to and Facilitators of the use of evidence by policymakers. *BMC Health Serv Res* 2014;14:2.

- 22 Court J, Young J. Bridging research and policy in international development: an Analytical and practical framework. *Development in Practice* 2006;16:85–90.
- 23 Hallett TB, Menzies NA, Revill P, *et al.* Using modeling to inform International guidelines for antiretroviral treatment. *AIDS* 2014;28 Suppl 1:S1–4.
- 24 Rhodes T, Lancaster K. How to think with models and targets: hepatitis C elimination as a numbering performance. *Int J Drug Policy* 2021;88:102694.
- 25 Kelly SL, Jaoude GJA, Palmer T, *et al.* Public health benefits of shifting from hospital-focused to ambulatory TB care in Eastern Europe: Optimising TB investments in Belarus, the Republic of Moldova, and Romania. *PLOS Glob Public Health* 2023;3:e0001025.
- 26 Christen P, Conteh L. How are mathematical models and results from mathematical models of vaccine-preventable diseases used, or not, by global health organisations *BMJ Glob Health* 2021;6:e006827.
- 27 Revill P, Rangaraj A, Makochekanwa A, *et al.* Perspectives on the use of Modelling and economic analysis to guide HIV programmes in sub-Saharan Africa. *Lancet HIV* 2022;9:e517–20.
- 28 Thompson J, McClure R, Blakely T, *et al.* Modelling SARS-Cov-2 disease progression in Australia and New Zealand: an account of an agent-based approach to support public health decision-making. *Aust N Z J Public Health* 2022;46:292–303.
- 29 Rhodes T, Lancaster K. Uncomfortable science: how mathematical models, and consensus, come to be in public policy. *Sociology Health & Illness* 2022;44:1461–80. 10.1111/1467-9566.13535 Available: <https://onlinelibrary.wiley.com/toc/14679566/44/9>
- 30 Gale NK, Heath G, Cameron E, *et al.* Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Med Res Methodol* 2013;13:117.
- 31 World Health Organization Regional Office for Europe. *A people-centred model of TB Care: Blueprint for EECA countries*. World Health Organization, 2017. Available: <https://www.euro.who.int/en/health-topics/communicable-diseases/tuberculosis/publications/2017/a-people-centred-model-of-tb-care-2017>
- 32 Innvaer S, Vist G, Trommald M, *et al.* Health policy-makers' perceptions of their use of evidence: a systematic review. *J Health Serv Res Policy* 2002;7:239–44.
- 33 Behrend MR, Basáñez M-G, Hamley JID, *et al.* Modelling for policy: the five principles of the neglected tropical diseases Modelling consortium. *PLOS Negl Trop Dis* 2020;14:e0008033.
- 34 Delva W, Wilson DP, Abu-Raddad L, *et al.* HIV treatment as prevention: principles of good HIV epidemiology Modelling for public health decision-making in all modes of prevention and evaluation. *PLoS Med* 2012;9:e1001239.
- 35 Lasry A, Richter A, Lutscher F. Recommendations for increasing the use of HIV/AIDS resource allocation models. *BMC Public Health* 2009;9:S8.
- 36 Adams S, Rhodes T, Lancaster K. New directions for Participatory Modelling in health: redistributing expertise in relation to Localised matters of concern. *Glob Public Health* 2022;17:1827–41.
- 37 Brownson RC, Chiqui JF, Stamatakis KA. Understanding evidence-based public health policy. *Am J Public Health* 2009;99:1576–83.
- 38 Lo NC, Andrejko K, Shukla P, *et al.* Contribution and quality of mathematical modeling evidence in world health organization guidelines: A systematic review. *Epidemics* 2022;39:100570.
- 39 Biesma RG, Brugha R, Harmer A, *et al.* The effects of global health initiatives on country health systems: a review of the evidence from HIV/AIDS control. *Health Policy Plan* 2009;24:239–52.
- 40 Avanceña ALV, Hutton DW. Optimization models for HIV/AIDS resource allocation: A systematic review. *Value Health* 2020;23:1509–21.
- 41 Revill P, Rollinger A, Richards S. *Thanzi La Onse 2021 annual report: Tanzi La Onse*. 2021. Available: <https://thanzi.org/wp-content/uploads/Thanzi-la-Onse-Programme-Report-2021.pdf>
- 42 *Thanzi La Onse (TLO): HIV Modelling Consortium, Institute for Global Health, UCL*, Available: <http://hivmodeling.org/model-database/thanzi-la-onse-tlo>
- 43 Micah AE, Su Y, Bachmeier SD. Health sector spending and spending on HIV/AIDS, tuberculosis, and malaria, and development assistance for health: progress towards sustainable development goal 3. *Lancet* 2020;396:693–724.
- 44 The Global Fund. *Focus on Sustainability, transition and Co-financing*. The Global Fund, 2017. Available: https://www.theglobalfund.org/media/8467/publication_sustainabilitytransition_cofinancing_focuson_en.pdf
- 45 South Eastern Europe Regional TB and HIV Community Network. *Sustainability of CSO provided HIV and TB Services During and After Transition in East Europe and Central Asia Region: Final report*. 2021. Available: <https://www.seercn.org/uimages/publications/Regional20survey20report20-20SEE20RCN.pdf>
- 46 Pudpong N, Viriyathorn S, Wanwong Y, *et al.* Public contracting with civil society organizations for HIV/AIDS service provisions: A key strategy to ending AIDS in Thailand. *J HIV/AIDS Soc Serv* 2021;20:285–301.