Journal of Benefit-Cost Analysis (2023), 14: S1, 16–54
doi:10.1017/bca.2023.23

CAMBRIDGE UNIVERSITY PRESS

ARTICLE

An Investment Case for the Scale-up and Use of Insecticide-Treated Nets Halfway into the SDG Targets

Rima Shretta and Randolph Ngwafor Anye

Nuffield Department of Medicine, University of Oxford, UK
Corresponding author: Rima Shretta; Email: rima.shretta@ndm.ox.ac.uk

Keywords: cost–benefit analysis; insecticide-treated nets; malaria; sustainable development goals; investment case

Abstract
This article examines a policy of scaling up LLINs by 10 percentage points from 2020 levels with a 90% cap in the 29 highest-burden countries in Africa along with social and behavioral change (SBC) and information education and communication (IEC) campaigns to increase the use and effectiveness of LLINs. The incremental cost of this scenario compared to a baseline of maintaining malaria interventions at 2020 levels has a present-day (2023) value of 5.7 billion US$ 2021 discounted at 8% over the period 2023–2030 (undiscounted starting at US$ 416 million in 2023 increasing to US$ 1.4 billion in 2030). This investment will prevent 1.07 billion clinical cases and save 1,337,069 lives. With standardized Copenhagen Consensus Center assumptions, the mortality benefit translates to a present value of US$ 225.9 billion. The direct economic gain is also substantial: the incremental scenarios lead to US$ 7.7 billion in reduced health system expenditure from the reduced treatment of cases, a reduction in the cost of delivering malaria control activities, and reduced household out-of-pocket expenses for malaria treatment. The productivity gains from averted employee and caretaker absenteeism and presenteeism add benefits with a present value of US$ 41.7 billion. Each dollar spent on the incremental scenario delivers US$ 48 in social and economic benefits.

1. Introduction

Between 2000 and 2015, malaria case incidence decreased by 37% globally, and malaria mortality rates decreased by 60%. Investments in malaria interventions have played a large part in achieving these reductions. However, financing for malaria has plateaued since 2015 with a corresponding flattening of progress. The year 2023 marks the halfway point to the 2016–2030 United Nations Sustainable Development Goals and the WHO Global Technical Strategy for malaria 2016–2030 pledge period. Given the recent setbacks, including funding declines and the more recent COVID-19 pandemic, progress toward reaching the targets has stalled. As a result, the Copenhagen Consensus has launched a research and advocacy project to encourage the world to focus on interventions that deliver the highest health and

economic value per dollar spent. The purpose of this study is to identify the most cost-effective malaria policy and quantify its socioeconomic return, using the cost–benefit analysis guidelines from the Copenhagen Consensus. The literature and the academic advisory group of the Copenhagen Consensus Center identify the increasing distribution of long-lasting insecticide-treated nets (LLINs) as the most effective malaria policy currently available. This article therefore specifically examines a policy of scaling up LLINs by 10 percentage points from 2020 levels with a 90% cap in the 29 highest-burden countries in Africa along with social and behavioral change communication (SBCC) and information education and communication (IEC) campaigns to increase the use and effectiveness of LLINs. The costs and epidemiological benefits of the intervention are generated using the SPPf transmission model that projects both costs and the decline of malaria cases and deaths with a scale-up of 1.25 percentage points per year over 8 years (2023 to 2030), along with information campaigns to ensure better use of nets.

The incremental cost of this scenario compared to a baseline of maintaining malaria interventions at 2020 levels has a present-day (2023) value of 5.7 billion US$ 2021 discounted at 8% over the period 2023–2030 (undiscounted starting at US$ 416 million in 2023 increasing to US$ 1.4 billion in 2030). This investment will prevent 1.07 billion clinical cases and save 1,337,069 lives. With standardized Copenhagen Consensus Center assumptions, the mortality benefit translates to a present value of US$ 225.9 billion. The direct economic gain is also substantial: the incremental scenarios lead to US $ 7.7 billion in reduced health system expenditure from the reduced treatment of cases, a reduction in the cost of delivering malaria control activities, and reduced household out-of-pocket expenses for malaria treatment. The productivity gains from averted employee and caretaker absenteeism and presenteeism add benefits with a present value of US$ 41.7 billion. Each dollar spent on the incremental scenario delivers US$ 48 in social benefits.

The evidence documented by this study can be used within a resource mobilization strategy to facilitate advocacy actions for increased investments in LLINs and social and behavior change communication (SBCC) for better usage of the nets toward reducing the burden of malaria.

2. Background

Between 2000 and 2015, the malaria case incidence decreased by 37% globally and malaria mortality rates by 60%. Investments in malaria interventions have played a large part in achieving these reductions, accounting for approximately 70% of the decline observed in sub-Saharan Africa between 2000 and 2015 (Bhatt *et al.,* 2015; Cibulskis *et al.,* 2016). Despite this progress, there were an estimated 247 million malaria cases and 619,000 malaria deaths worldwide in 2021, with 90% of all deaths occurring in the high-burden countries in Africa (WHO, 2022). According to the *World Malaria Report* (2022), four countries – Nigeria (27%), the Democratic Republic of the Congo (12%), Uganda (5%), and Mozambique (4%) – accounted for almost half of all malaria cases globally, with children under five years of age and pregnant women being the most vulnerable (WHO, 2022). In addition, malaria has societal and economic consequences beyond the direct costs of prevention and treatment and has been shown to be both a

https://doi.org/10.1017/bca.2023.23 Published online by Cambridge University Press

consequence and a cause of poverty (Sachs & Malaney, 2002). Efforts to prevent, control, and eliminate malaria both contribute to and benefit from sustainable development. The objectives of reducing the disease burden and eliminating malaria are intrinsically linked to most of the Sustainable Development Goals (SDGs) and are central to SDG 3: *Ensure healthy lives and promote well-being for all at all ages* and its Target 3.3: "By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases" (United Nations, 2015). The Global Technical Strategy (GTS) for malaria 2016–2030, developed in the same year, called for a 90% reduction in global malaria incidence and deaths by 2030 and estimated that to achieve these targets, an annual additional malaria investment of an estimated total of US$ 7.14 billion per year by 2025 and US$ 8.32 billion by 2030 is needed (WHO, 2015).

The year 2023 marks the halfway point to the 2016–2030 SDGs and GTS pledge period. However, financing for malaria has plateaued since 2015, commensurate with a leveling of the progress achieved. In addition, the COVID-19 pandemic, in particular COVID-19 mitigation measures and people's fears around contracting it, made the implementation of malaria prevention and treatment activities more expensive: countries were unable to implement malaria prevention activities and many households did not seek (or were not able to receive) treatment. These combined setbacks have stalled the progress toward reaching both the SDG and the GTS targets (WHO, 2022). The Copenhagen Consensus Center has launched a research and advocacy project to encourage the world to focus on the smart things first – in other words, programs that deliver the most per dollar spent.

Economic evaluations have shown that LLINs and SBCC for the prevention of malaria are among the most cost-effective malaria control interventions currently available (Stevens *et al.,* 2005; Mueller *et al.,* 2008; Yukich *et al.,* 2009; Kolaczinski *et al.,* 2010; Morel *et al.,* 2013; Renggli *et al.,* 2013; Smith Paintain *et al.,* 2014; Conteh *et al.,* 2021). However, there are increasing concerns about pyrethroid resistance (Sovi *et al.,* 2020) and an acknowledgment that next-generation nets will be more expensive than those that are currently used. In addition, there are concerns about the durability of nets, with reports that in some areas, they do not last for the full three years under field conditions (Killian *et al.* 2021). For the purposes of this analysis, we have assumed that 30% of the standard LLINs are replaced with chlorfenapir LLINs and that the intervention remains effective. We have used the average price of US$ 2.68 for a distributed standard LLIN and US$ 3.90 for a distributed chlorfenapir LLIN, and the upper bound of the modeled-cost range for LLIN and SBCC.

This article outlines the evidence for scaling up existing coverage of LLINs by 10 percentage points with a cap of 90% and presents an investment case for greater investment in this area in the 29 highest-burden countries in Africa: Nigeria, Democratic Republic of Congo (DRC), Tanzania, Mozambique, Uganda, Burkina Faso, Mali, Niger, Angola, Cote d'Ivoire, Cameroon, Chad, Kenya, Ghana, Benin, Guinea, Ethiopia, Madagascar, Zambia, Sierra Leone, South Sudan, Sudan, Malawi, Burundi, Central African Republic (CAR), Liberia, Senegal, Togo, and Rwanda. Ten of these countries have been identified as high-burden to high-impact countries in which aggressive new approaches that will jumpstart progress against malaria will be supported by WHO and the RBM Partnership to End Malaria, among other partners (WHO, 2018).

https://doi.org/10.1017/bca.2023.23 Published online by Cambridge University Press

3. Methodology

3.1. Literature review

A rapid literature review was initially conducted to summarize and update available cost-effectiveness evidence data for malaria control and elimination. Several literature reviews have previously been conducted on the economics of malaria prevention and treatment (Shretta *et al.,* 2016; Conteh *et al.,* 2021). This review therefore focused on new articles published after 2019. Details on the literature review can be found in Appendix A.

3.2. Transmission model

The fundamental epidemiological and basic economic model used here is the Single Patch *Plasmodium falciparum* (SPPf) tool. This spatially explicit, compartmental, nonlinear, ordinary differential equation transmission model is an extension of previously published models and has been implemented in R and C++ (White *et al.,* 2009; Silal *et al.,* 2014; Silal 2019; Silal *et al.,* 2019). The economic evaluation presented here uses the outputs of this transmission model as described below.

Key features of the model include four infection classes representing infections that are severe, clinical, asymptomatic and detectable by microscopy, and asymptomatic and undetectable by microscopy, with each infection class having an associated infectiousness based on infectivity data. The probability of individuals entering each class of infection is dependent on their immunity status. It is assumed that untreated individuals will transition from higher to lower severity infection classes as they recover and that they can be boosted to higher severity classes through superinfection. It is assumed that treated individuals test positive for histidine-rich protein 2 (HRP2) after clearance of asexual parasitaemia for different durations depending on the detection limit of the test used. Other additional features were subnational climatic variation (seasonality) and importation of infection. More details on the model and the parameters driving the model can be found on GitHub (2020).

3.3. Data

The data used to calibrate the model were obtained from several sources. The main estimates for cases and deaths stem from the latest updated *World Malaria Report 2022*, covering the period 2000–2021. To mitigate skewing the model outputs with the malaria program disruptions caused by COVID-19, data points beyond 2019 were not used for the model. When unavailable in the newest update, we have also extracted specific information from the *World Malaria Reports* for the period 2001 to 2021. The data collected covers Non-community cases; Community cases; Number of LLINs sold or delivered; Number of people protected by IRS; Reported fatalities due to malaria; Population at risk (high, low transmission, and active foci); Coverage of first-line treatment; and Coverage of RDT (years available).

Owing to differing reporting standards and interpretations of community cases, both community and non-community cases were grouped together. Where parameters driving the model could not be estimated from available data, they were sourced from existing literature.

The scenarios modeled including the assumptions are shown in Table 1.

In all countries, interventions to increase use beyond the estimated proportions implemented in 2019 were added to simulate increased net *use*. The interventions modeled were a

https://doi.org/10.1017/bca.2023.23 Published online by Cambridge University Press

Table 1. *Scenarios modeled.*

Description	Assumptions
Baseline scenario (business as usual)	
Malaria control activities maintained throughout 2023–30 at their 2019 levels. Passive testing and treating of positive malaria cases (community- and facility-based) maintained at 2019 levels Distribution of LLINs with coverage* and usage levels maintained at 2019 levels IRS (Indoor Residual Spraying) coverage continued at 2019 levels Seasonal malaria chemoprophylaxis continued at 2019 coverage levels IPTp (intermittent preventive treatment of malaria in pregnancy) continued at 2019 levels Distribute routine LLINs to participants of IPTp 30% of LLINs distributed 2023–30 are chlorfenapir LLINs, 70% standard LLINs	No cost and service differences between community- and facility-based treatment avenues Routine distribution of LLINs through antenatal clinics and well-childcare Mass distribution of LLINs every 3 years, at coverage levels consistent with current data Proportion of participants who take IPTp remains constant Net durability: 3 years 30% of LLIN were chlorfenapir and are effective throughout 2023–30
LLIN scale-up scenario	
Baseline + Scale-up of LLIN coverage to 10 percentage points above the 2019 level (capped at 90%) between 2023–2030 These additional LLINs will consist of 30% chlorfenapir LLINs, 70% standard LLINs SBCC to increase the usage of LLINs	Mass distribution of LLINs every 3 years. Net durability: 3 years SBCC costs applied to cover 1/3 of the country per year, allowing for full coverage with every mass distribution Costs applied annually at 1/3 coverage per population at risk Impact of SBCC, hang-up campaigns, and other interventions to enable increase in effective coverage by 10 percentage points

Note: *LLIN effectiveness, usage × proportion of bites averted.

combination of activities of a "hang-up campaign" as well as SBC and IEC, where LLIN coverage and use increased by 10 percentage points by 2030.

4. Economic evaluation of avoided cases and deaths

Various sources were used for cost estimates. Country-level data were used when available either directly from countries or from literature sources. Where country-specific data were

https://doi.org/10.1017/bca.2023.23 Published online by Cambridge University Press

Table 2. *Framework for estimating the benefits of reduced burden of malaria.*

Direct health system cost savings	Direct household cost savings	Indirect benefits
National and subnational expenditures on malaria treatment	Out-of-pocket expenditures	Productivity losses among malaria patients and caregivers Value of life years lost due to premature death

unavailable, proxies were used. The cost inputs used are outlined in Appendix B. This evidence formed the basis for estimating the unit costs and benefits of scaling up coverage with LLINs and SBCC.

The investment case projects the financial requirements for the two scenarios through 2030 and values the social, economic, and financial returns of reducing malaria transmission compared to the baseline scenario maintaining the coverage level of 2019.

Using a societal perspective and cost of illness approach (Drummond *et al.,* 2002), the economic burden of malaria was evaluated. A reduction in malaria illness leads to costs averted that would have otherwise occurred. Three types of costs were estimated: (a) direct health costs, (b) direct household costs, and (c) indirect costs to households and the health system (see Table 2; Drummond *et al.,* 2002). All monetary figures are expressed in 2021 constant US$.

4.1.1. Direct cost savings to the health service

The total direct cost savings resulting from fewer malaria cases was estimated using data from published literature at the national level (see Appendix B). Where no data were available, proxies were used from other countries or the literature. The findings reflect the vertical costs to the malaria program and the publicly funded system costs of implementing the malaria intervention. Cost estimates expressed in international (PPP) US$ value were converted to 2021 constant US$ values.

4.1.2. Direct cost savings to households

Malaria exerts a significant financial burden on households. Malaria patients often pay for transportation to access health facilities, diagnostic services, and medicines. In many countries in Africa, although testing and treatment for malaria and antimalarials are free, prepaid, or covered by capitation of the National Health Insurance Schemes, malaria patients still incur out-of-pocket expenditures (OOP) (Nabyonga et al, 2013; RBM, 2015). To estimate direct household costs for malaria, the number of reported outpatient (OP) and inpatient (IP) malaria cases was multiplied by the mean OOP spending, which included the cost of transportation (separately for OP and IP cases).

4.1.3. Indirect benefits to society

The economic impact of malaria extends beyond the health system. Patients forego income while recovering from malaria, caregivers looking after ill children and the elderly also lose

https://doi.org/10.1017/bca.2023.23 Published online by Cambridge University Press

out on potential earnings, and children missing out on school affect human capital accumulation. Premature deaths also cost society through losses in lifetime productivity and in the value that people place on living longer, healthier lives.

To evaluate the economic impact of malaria-related morbidity, the income lost for malaria patients and caregivers was estimated. The estimated income per worker was derived from GDP per capita adjusted for labor force participation and labor share of GDP. The resulting figure was used as a proxy for lost worker income, the time value of non-working adults (15 years and older) was reduced by 50%, and a zero value of time was assigned to children under 15 years old. The incidence of malaria for each country reported in Global Burden of Disease for 2019 (IHME, 2021) was used to estimate the share of children and adults, respectively. For each age group, the value of the lost productivity was multiplied by the duration of OP and IP illness from published literature and the number of reported OP and IP cases. In addition, the effect of reduced productivity from "presenteeism" was calculated by assuming that adults returning to work after malaria illness would be 50% less productive for an additional three days.

Averted mortality is valued using a standardized approach across all *Halftime SDG* papers, which follows the recommendations of Robinson *et al.* (2019).

To estimate the value of averted mortality, we use the U.S. Value of Statistical Life (VSL) US$ 9.4 million (2015 US$) as reference, which represents approximately 160 times income as measured by income per capita PPP. The relationship is transferred to the entire low- and lower–middle-income population via the ratio of GDP per capita, using an income elasticity of 1.5.

To estimate these values, we take the population-weighted GDP per capita figure in 2020 Int$ for the group of LLMCs and the United States of America, and estimate the VSL at time $t = 0$, 2020.

$$VSL_t = \left(\frac{Int\$\ GDPpc_{LLMC,t}}{Int\$\ GDPpc_{USA,t}}\right)^{e-1} * 160 * GDPpc_{LLMC,t}$$

Following Cropper *et al.* (2019), we estimate each subsequent VSL in the time series according to the following formula:

$$VSL_{t+1} = VSL_t * (1 + g_t)^e$$

where *gt* is the real GDP per capita growth rate between period *t* and *t* + 1 (SSP Database, IIASA GDP Model, Scenario SSP2_v9_130219) and e = 1.5. The value per statistical life year (VSLY) is calculated by dividing the VSL by half the life expectancy at birth.

The GDP growth in this group of countries outpaces population growth so that VSLY grows rapidly over time. In constant 2021 US$ values, the benefit of averting a life year lost (VSLY) is US$ 3,732 (2023), US$ 5,049 (2025), and US$ 6,062 (2030).

Using the distribution of malaria deaths between age groups by country reported in the Global Burden of Disease (GBD 2019), and assuming 2.5 years as the average death among children under 5 years, 12 years among children aged 5–19, and half the remaining life expectancy for adults over 20 years. The average life expectancy of males and females was used to estimate the number of years of life lost and then multiplied by the value of an additional life year (VSLY) for low-income and low–middle-income countries (all deaths valued equal). Data on life expectancy was retrieved from World Bank data.

https://doi.org/10.1017/bca.2023.23 Published online by Cambridge University Press

Table 3. *Unit costs used for estimating intervention scale-up costs.*

Item	US$ constant 2021
A distributed standard LLIN	average price US$ 2.68
A distributed chlorfenapir LLIN	average price US$ 3.90
Cost of SBCC per distributed LLIN	average price US$ 0.10

4.2. Cost projections

Unit costs (see Table 3) were used in the SPPf model to calculate the cost of the scenarios and the additional costs of the LLIN and SBCC scale-up scenario compared to the baseline scenario.

4.3. Benefits estimation

The benefits of each scenario were estimated as the sum of the direct cost savings to the health system from reduced use of outpatient and inpatient health services and reduction in the cost of delivering malaria control activities, the direct cost savings to households, and the indirect cost savings of reduced morbidity and mortality from malaria calculated above. These were computed using the outputs of the transmission model: the malaria cases and deaths averted in the scale-up scenario compared to the baseline scenario were calculated and valued using the same methods described previously for estimating the economic burden of malaria (see Table 2).

Each of these was estimated for each of the 29 countries and added together to obtain the total cases and deaths averted, the total costs, and the total benefits.

The Net Present Value (NPV) was calculated to obtain the present value of the future revenue generated from reducing the burden of malaria using standard economic techniques. The purpose was to give a true picture of the financial value of an investment today. The timeframe used for calculating the NPV was 7 years (2023–2030) and an 8% discount rate was applied.

4.4. Benefit–cost ratio

The BCR is interpreted as the economic return from every additional dollar spent on malaria above the baseline scenario. To calculate the BCR, the NPV of the incremental benefits of the scale-up scenario compared to baseline was divided by the NPV of the incremental cost of the scale-up scenario (compared to the baseline).

4.5. Sensitivity analysis

A stochastic sensitivity analysis on the epidemiological and cost outputs of the malaria transmission model was performed. The minimum, median, and maximum malaria cases and deaths predicted by the model for each scenario were used to calculate the minimum, median, and maximum costs. Three hundred random samples were drawn, which generated

https://doi.org/10.1017/bca.2023.23 Published online by Cambridge University Press

a range of costs. From the range of costs generated, the minimum, maximum, and median percentiles are presented.

4.6. Limitations

This report has several limitations. Due to time and resource constraints, the transmission model generated national transmission-based estimates based on the *World Malaria Report.* Higher levels of spatial heterogeneity would need to be modeled to enable more accurate subnational estimates of benefits and costs. The costs of interventions have been estimated based on available published data and proxies when data were unavailable. For example, the costs of outpatients and inpatients were derived from WHO/CHOICE. As countries move closer to elimination, the impact of active surveillance on both the epidemiology and the cost will also need to be included. This was not included due to a lack of historical data to enable fitting the model for impact or cost.

While employee absenteeism was included in the estimates of benefits, the analysis did not include the economic benefits conferred by reductions in school absenteeism and subsequent improvements in cognitive development due to the limited empirical evidence to enable converting these estimates to wages earned (Kuecken *et al.,* 2020). Other benefits not included include potential benefits on tourism and the impact of economic development and housing improvements on malaria transmission, as well as regional or cross-border externalities.

Households spend substantial amounts of money on malaria preventive tools such as insecticide sprays and repellants. These costs were not included in this study, thereby possibly underestimating the direct household costs of malaria. In addition, infection with malaria is likely to result in a higher likelihood of death from other causes such as HIV and newborn mortality. These additional impacts are not included.

Last, the effectiveness of LLINs at reducing bites is assumed to be 40%. However, this may be an overestimate given recent concerns with pyrethroid resistance and net durability (Kilian *et al.,* 2021). New, more costly nets are likely to be needed in the future, and resistance management strategies will need to be deployed. To accommodate additional costs of maintaining effectiveness, we calculated the average price of an LLIN assuming 30% of the standard nets are replaced with chlorfenapir nets, and in addition, adopted the higher-end range of the ITN and SBCC scale-up cost estimate.

5. Findings

5.1. Rapid literature review

In total, 53 articles were screened for eligibility. After screening, 48 articles were included in the analysis, with the majority of articles published in 2020 and 2021 (19 and 16, respectively). Reasons for exclusion were opinion paper (1), discrete choice experiment (1), protocol (1), severe malaria incidence (1), and *Plasmodium vivax* (1). The total number of countries included in all studies was 24, with the majority of countries being in sub-Saharan Africa. The majority of the studies were cost-effectiveness analyses (80.9%), with the least being cost-saving analyses and investment cases (4.3% each). Some 83% of studies were focused on malaria control, while 17% were focused on malaria elimination. The number of studies with more than one economic outcome reported was just 18. The studies employed

https://doi.org/10.1017/bca.2023.23 Published online by Cambridge University Press

heterogeneous inputs and methodologies preventing cross-comparisons and an overall synthesis of all the outputs. Summaries of the review are presented in Appendix A.

These and previously published studies affirm that interventions to prevent malaria, particularly the use of LLINs, are highly cost-effective across different settings using different distribution channels. The use of LLINs in combination with improved SBCC is therefore considered in this article to be among the most cost-effective policies for scaling up in the control setting at the present time.

5.2. Transmission model predictions and projections

5.2.1. Baseline response

Maintaining the interventions (LLIN distribution, IRS, SMC) and health-system access and performance at 2019 levels does not change the transmission intensity. Figure 1 shows that malaria is predicted to continue unabated, with no further decrease expected until 2030 (the endpoint of the model). The slight upward trend in cases and deaths reflects a growing population, rather than an increased incidence of malaria.

5.2.2. Scale-up LLIN and SBCC coverage by 10 percentage points

Figure 2 illustrates the projected clinical cases and deaths with scaled-up LLIN and SBCC with the baseline (where other interventions were held constant). In the LLIN and SBCC scenario, clinical cases fell from 4.17 billion to 3.10 billion, and deaths from 4,823,000 to 3,486,000. Scale-up and better use of LLINs resulted in a projected 1.07 billion clinical cases and 1,337,000 deaths averted cumulatively over eight years.

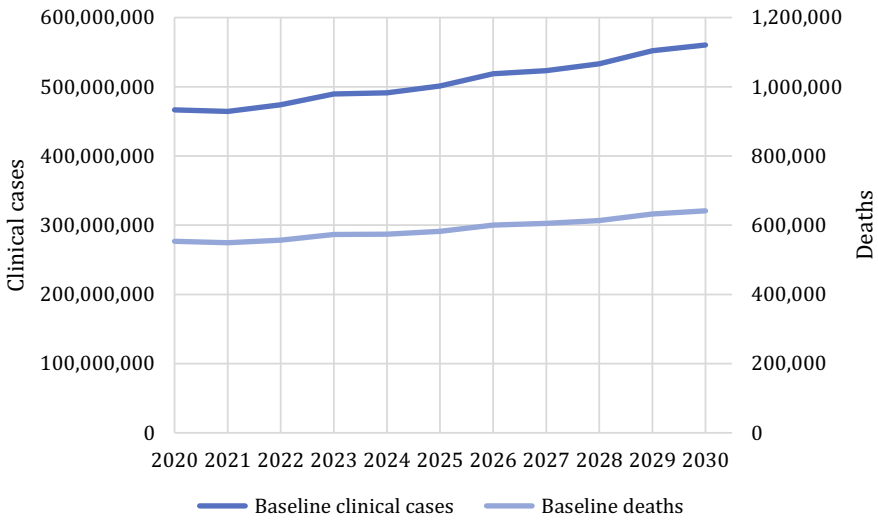

Figure 1. *Baseline clinical cases and deaths per year.*

https://doi.org/10.1017/bca.2023.23 Published online by Cambridge University Press

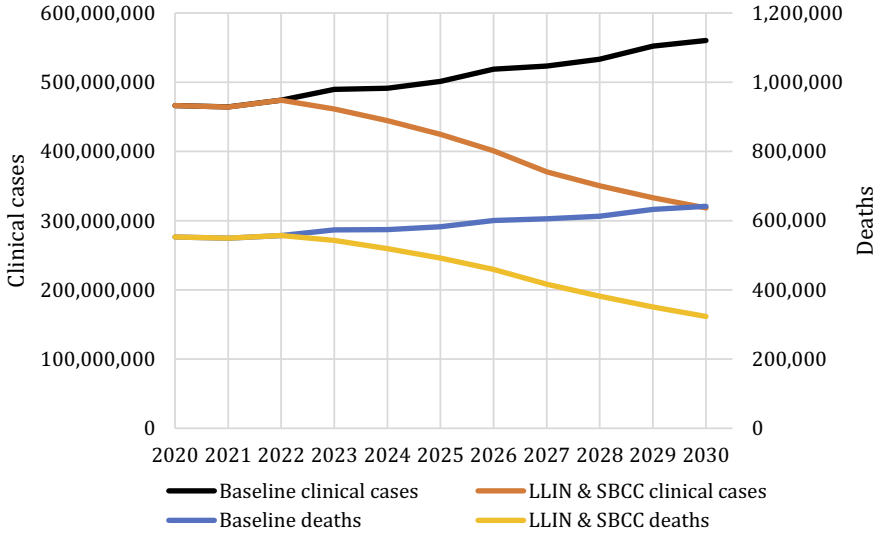

Figure 2. *LLIN and SBCC scenario versus baseline scenario.*

5.3. Cost projections

To account for potential underestimation of the cost of combating pyrethroid resistance and to maintain the effectiveness of LLINs throughout the period, the upper bound range of the cost estimate for the LLIN and SBCC program produced by the SPPf model is used for reporting the main scenario. The medium cost was used for all other cost estimates.

Adding up all the costs of malaria interventions for maintaining the 2019 levels and the resulting costs of treatment to the health system and out-of-pocket expenses for households, the total estimated present value for 2023 to 2030 discounted at 8% is US$ 53.1 billion (min-max range US$ 51.7–54.4 billion). The total cost of the LLIN and SBCC scenario was estimated to be US$ 49.3 billion (min-max range US$ 47.1–50.6 billion) between 2023 and 2030.

Comparing the two scenarios, the incremental costs of scaling up the LLIN and SBCC program is US$ 5.7 billion in total over 7 years discounted at 8%. The undiscounted costs gradually increase by year as more nets are purchased and distributed with social and behavior change communication (see Figure 3).

The incremental costs for treating malaria cases for the health system and out-of-pocket for households decrease as LLIN and SBCC scale-up reduces the number of malaria cases. Therefore, the total net cost of the LLIN and SBCC scenario is lower than the cost of the baseline scenario.

In the cost–benefit analysis, the cost savings obtained from reduced outpatient and inpatient health-system expenditures due to diminishing cases and reduced out-of-pocket household expenses are added to the benefits. These financial benefits of scaling up LLINs and SBCC will outweigh the expenses for additional LLINs and SBCC in the year 2026. Figure 4 illustrates the total costs of increasing the coverage of LLINs (same as Figure 3) and the total financial cost savings. Costs rise throughout the period of scale-up due to increased

https://doi.org/10.1017/bca.2023.23 Published online by Cambridge University Press

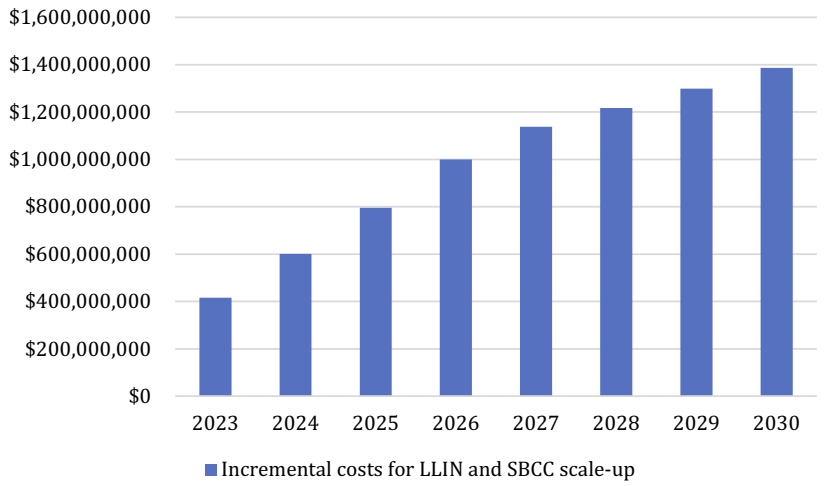

Figure 3. *Total incremental costs of increasing the coverage of LLINs and SBCC.*

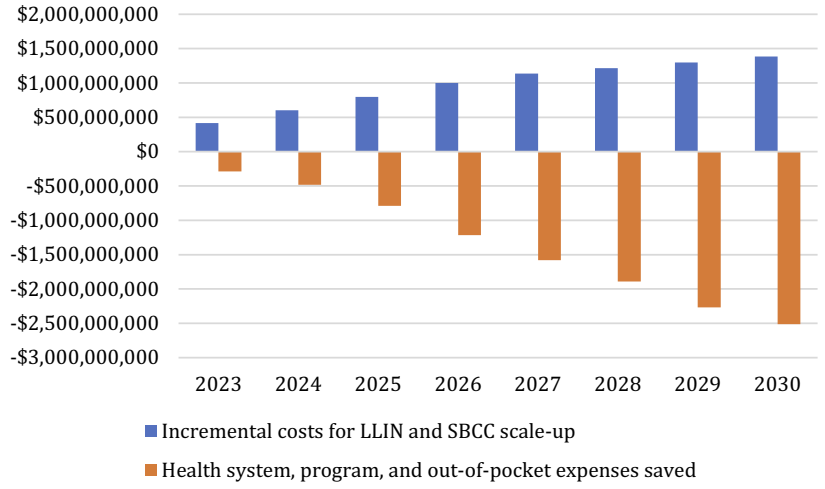

Figure 4. *Year-by-year comparison of incremental costs for LLIN and SBCC, and expenses saved due to reduction in malaria cases.*

investments for LLIN purchase, distribution, and use, while healthcare cost savings increase even more over the entire period as fewer and fewer people get sick.

5.4. Benefits estimation

In 2023–2030, the LLIN and SBCC scenario will generate economic benefits of US$ 275.4 billion (NPV 8%). The majority of the benefit is derived from life years saved, US$ 225.9 billion, the avoided productivity loss for patients and caregivers adds US$ 41.7 billion in

https://doi.org/10.1017/bca.2023.23 Published online by Cambridge University Press

economic benefits, and the avoided healthcare system spending and out-of-pocket expenses for malaria treatment adds financial benefits of US$ 7.7 billion (NPV 8%) (Figure 5).

5.5. Benefit–cost ratio

Implementing the LLIN and SBCC scenario (in addition to the baseline scenario of maintaining coverage) over the period 2023–2030 is estimated to produce a return on investment (BCR) of 48:1 (the high-end model cost range for ITNs was used for a moderate estimate due to the pyrethroid resistance challenges, therefore the BCR range is 48–57). The BCR estimates for the 29 individual countries range from 9 to 128 (see Appendix C).

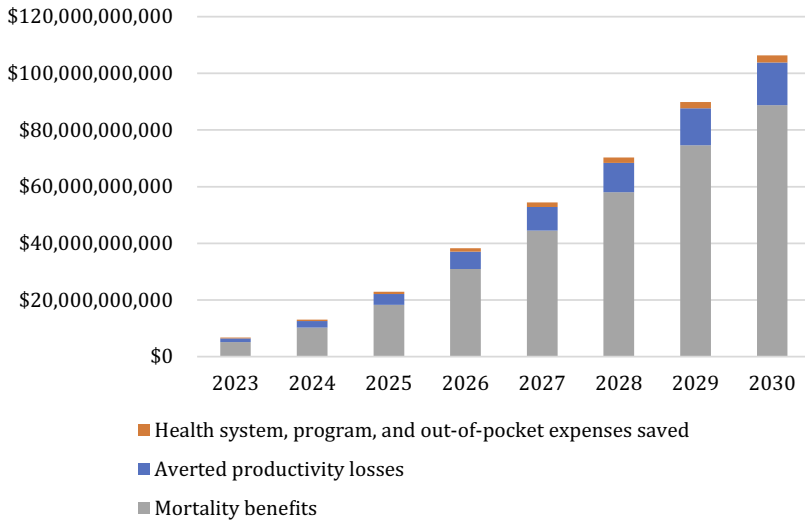

Figure 5. *Mortality benefits, averted productivity losses, and expenses saved due to reduction in malaria cases from scale-up in LLIN and SBCC compared to baseline.*

Table 4. *Summarized results of incremental costs and benefits of the LLIN and SBCC scale-up scenario compared to baseline (2023–2030).*

Incremental clinical cases averted	1,066,316,189
Incremental deaths averted	1,337,069
Incremental benefits	US$ 275 billion (NPV 8%) US$ 7 billion in 2023 rising to US$ 106 billion in 2030
Incremental cost	US$ 5.7 billion (US$ 4.9–5.7) (NPV 8%) US$ 416 million in 2023 rising to US$ 1.4 billion in 2030
BCR	48 (48–57)

https://doi.org/10.1017/bca.2023.23 Published online by Cambridge University Press

6. Conclusion

The findings indicate that the interventions implemented in 2019 are not likely to lower malaria transmission substantially. Scaling up the coverage and using LLINs while maintaining the baseline 2019 interventions will have an incremental cost of US$ 5.7 billion (discounted at 8%) and generate estimated economic benefits of US$ 275 billion with a BCR of 48:1. This analysis can be used by partners needing to increase their resource mobilization efforts to achieve the global malaria goals.

Acknowledgments. The authors would like to thank Catherine Pitt of the London School of Hygiene and Tropical Medicine, Lesong Conteh of the London School of Economics, Jessica Cohen of Harvard University, Joshua Yukich of Tulane University, Obinna Onwujekwe of the University of Nigeria, and Bjorn Lomborg of the Copenhagen Consensus Center for their valuable comments that supported this analysis. All responsibility for the content remains that of the authors.

References

Agius, P. A., J. C. Cutts, Oo. W. Han, A. Thi, K. O'Flaherty, K. Zayar Aung, *et al.* 2020. "Evaluation of the Effectiveness of Topical Repellent Distributed by Village Health Volunteer Networks Against Plasmodium Spp. Infection in Myanmar: A Stepped-Wedge Cluster Randomised Trial." *PLoS Medicine*, *17*(8): e1003177.

Alonso, S., C. J. Chaccour, J. Wagman, B. Candrinho, R. Muthoni, A. Saifodine, *et al.* 2021. "Cost and Cost-Effectiveness of Indoor Residual Spraying with Pirimiphos-Methyl in a High Malaria Transmission District of Mozambique with High Access to Standard Insecticide-Treated Nets." *Malaria Journal*, *20*(1): 143.

Arroz, J. A. H., B. Candrinho, C. Mendis, M. Lopez, and M. Martins. 2019. "Cost-Effectiveness of Two Long-Lasting Insecticidal Nets Delivery Models in Mass Campaign in Rural Mozambique." *BMC Research Notes*, *12*(1): 578.

Assebe, L. F., X. J. Kwete, D. Wang, L. Liu, O. F. Norheim, A. Jbaily, *et al.* 2020. "Health Gains and Financial Risk Protection Afforded by Public Financing of Selected Malaria Interventions in Ethiopia: An Extended Cost-Effectiveness Analysis." *Malaria Journal*, *19*(1): 41.

Aung, Y. N., S. T. T. Tun, V. Vanisaveth, K. Chindavongsa, and L. Kanya. 2022. "Cost-Effectiveness Analysis of G6PD Diagnostic Test for Plasmodium Vivax Radical Cure in Lao PDR: An Economic Modelling Study." *PLoS One*, *17*(4): e0267193.

Baral, R., A. Levin, C. Odero, C. Pecenka, C. Tabu, F. Mwendo, *et al.* 2021. "Costs of Continuing RTS,S/ASO1E Malaria Vaccination in the Three Malaria Vaccine Pilot Implementation Countries." *PLoS One*, *16*(1): e0244995.

Bath, D., J. Cook, J. Govere, P. Mathebula, N. Morris, K. Hlongwana, *et al.* 2021. "Effectiveness and Cost-Effectiveness of Reactive, Targeted Indoor Residual Spraying for Malaria Control in Low-Transmission Settings: A Cluster-Randomised, Non-Inferiority Trial in South Africa." *The Lancet*, *397*(10276): 816–827.

Bath, D., C. Goodman, and S. Yeung. 2020. "Modelling the Cost-Effectiveness of Introducing Subsidised Malaria Rapid Diagnostic Tests in the Private Retail Sector in Sub-Saharan Africa." *BMJ Global Health*, *5*(5): e002138.

Bell, G. J., M. Loop, H. M. Topazian, M. Hudgens, T. Mvalo, J.J. Juliano, *et al.* 2020. "Case Reduction and Cost-Effectiveness of the RTS,S/AS01 Malaria Vaccine Alongside Bed Nets in Lilongwe, Malawi. *Vaccine*, *38*(25): 4079–4087.

Bhatt, S., D. J. Weiss, E. Cameron, D. Bisanzio, B. Mappin, U. Dalrymple, *et al.* 2015. "The Effect of Malaria Control on Plasmodium Falciparum in Africa Between 2000 and 2015." *Nature 526*(7572): 207–211.

Brito-Sousa, J. D., H. M. Peixoto, A. Devine, A. V. Silva-Neto, P. C. S. Balieiro, V. S. Sampaio, *et al.* 2022. "Real-Life Quantitative G6PD Screening in Plasmodium Vivax Patients in the Brazilian Amazon: A Cost-Effectiveness Analysis." *PLOS Neglected Tropical Diseases*, *16*(3): e0010325.

Canana, N. 2021. "A Cost Analysis to Address Issues of Budget Constraints on the Implementation of the Indoor Residual Spray Programme in Two Districts of Maputo Province, Mozambique." *Malaria Journal*, *20*(1): 8.

Cibulskis, R. E., P. Alonso, J. Aponte, M. Aregawi, A. Barrette, L. Bergeron, *et al.* 2016. "Malaria: Global Progress 2000–2015 and Future Challenges." *Infectious Diseases of Poverty*, *5*(1): 61.

Cirera, L., B. Galatas, S. Alonso, K. Paaijmans, M. Mamuquele, H. Marti-Soler, *et al.* 2020. "Moving Towards Malaria Elimination in Southern Mozambique: Cost and Cost-Effectiveness of Mass Drug Administration Combined with Intensified Malaria Control." *PLoS One 15*(7): e0235631.

https://doi.org/10.1017/bca.2023.23 Published online by Cambridge University Press

Coleman, S., Y. Yihdego, E. Sherrard-Smith, C. S. Thomas, D. Dengela, R. M. Oxborough, *et al.* 2021. "Partial Indoor Residual Spraying with Pirimiphos-Methyl as an Effective and Cost-Saving Measure for the Control of Anopheles Gambiae S.L. in Northern Ghana." *Scientific Reports*, *11*(1): 18055.

Conner, R. O., Y. Dieye, M. Hainsworth, A. Tall, B. Cisse, F. Faye, *et al.* 2020. "Mass Testing and Treatment for Malaria Followed by Weekly Fever Screening, Testing and Treatment in Northern Senegal: Feasibility, Cost and Impact." *Malaria Journal*, *19*(1): 252.

Conteh, L., K. Shuford, E. Agboraw, M. Kont, J. Kolaczinski, and E. Patouillard. 2021. "Costs and Cost-Effectiveness of Malaria Control Interventions: A Systematic Literature Review." *Value Health 24*(8): 1213–1222.

Cropper, M. L., *et al.* 2019. "Applying Benefit-Cost Analysis to Air Pollution Control in the Indian Power Sector." *Journal of Benefit-Cost Analysis*, *10*(S1): 185–205. https://doi.org/10.1017/bca.2018.27.

Dasgupta, R. R., W. Mao, and O. Ogbuoji. 2022. "Addressing Child Health Inequity Through Case Management of Under-Five Malaria in Nigeria: An Extended Cost-Effectiveness Analysis." *Malaria Journal*, *21*(1): 81.

Devine, A., R. E. Howes, D. J. Price, K. A. Moore, B. Ley, J. A. Simpson, *et al.* 2020. "Cost-Effectiveness Analysis of Sex-Stratified Plasmodium Vivax Treatment Strategies Using Available G6PD Diagnostics to Accelerate Access to Radical Cure." *American Journal of Tropical Medicine and Hygiene*, *103*(1): 394–403.

Diawara, H., P. Walker, M. Cairns, L. C. Steinhardt, F. Diawara, B. Kamate, *et al.* 2021. "Cost-Effectiveness of District-Wide Seasonal Malaria Chemoprevention When Implemented Through Routine Malaria Control Programme in Kita, Mali Using Fixed Point Distribution." *Malaria Journal*, *20*(1): 128.

Drummond M., M. Sculpher, G. Torrance, B. O'Brien, and G. Stoddart. 2005. *Methods for The Economic Evaluation of Health Care Programmes* 3 ed. Oxford University Press.

Du, Y. Q., X. X. Ling, J. J. Jin, H. Y. Zhou, S. Zhu, G. D. Zhu, *et al.* 2020. "Cost-Effectiveness Analysis of Malaria Rapid Diagnostic Test in the Elimination Setting." *Infectious Diseases of Poverty*, *9*(1): 135.

Fernandes, S., V. Were, J. Gutman, G. Dorsey, A. Kakuru, M. Desai, *et al.* 2020. "Cost-Effectiveness of Intermittent Preventive Treatment with Dihydroartemisinin–Piperaquine for Malaria During Pregnancy: An Analysis Using Efficacy Results from Uganda and Kenya, and Pooled Data." *The Lancet Global Health*, *8*(12): e1512–e1523.

Galactionova, K., M. Velarde, K. Silumbe, J. Miller, A. McDonnell, R. Aguas, *et al.* 2020. "Costing Malaria Interventions From Pilots to Elimination Programmes." *Malaria Journal*, *19*(1): 332.

Gilmartin, C., J. Nonvignon, M. Cairns, P. Milligan, F. Bocoum, P. Winskill, *et al.* 2021. "Seasonal Malaria Chemoprevention in the Sahel Subregion of Africa: A Cost-Effectiveness and Cost-Savings Analysis." *The Lancet Global Health*, *9*(2): e199–e208.

GitHub. 2020. *Single Patch Plasmodium Falciparum (SPPf) Tool* [Internet]. Available at https://github.com/sheetalsilal/SPPf_tool.

IHME. 2021. *Global Burden of Disease 2019.* Available at https://vizhub.healthdata.org/gbd-compare/.

Kilian, A., E. Obi, P. Mansiangi, A. P. Abílio, K. A. Haji, S. Blaufuss, *et al.* 2021. "Variation of Physical Durability Between LLIN Products and Net Use Environments: Summary of Findings from Four African Countries." *Malaria Journal*, *20*(1): 26.

Kim, S., V. N. Luande, J. Rocklov, J. M. Carlton, and Y. Tozan. 2021. "A Systematic Review of the Evidence on the Effectiveness and Cost-Effectiveness of Mass Screen-and-Treat Interventions for Malaria Control." *American Journal of Tropical Medicine and Hygiene*, *105*(6): 1722–1731.

Kim, J. H., J. Suh, W. J. Lee, H. Choi, J. D. Kim, C. Kim, *et al.* 2021. "Modelling the Impact of Rapid Diagnostic Tests on Plasmodium Vivax Malaria in South Korea: A Cost-Benefit Analysis." *BMJ Global Health*, *6*(2): e004292.

Kolaczinski, J. H., K. Kolaczinski, D. Kyabayinze, D. Strachan, M. Temperley, N. Wijayanandana, *et al.* 2010. "Costs and Effects of Two Public Sector Delivery Channels for Long-Lasting Insecticidal Nets in Uganda." *Malaria Journal*, *9*: 102.

Kostic, M., M. N. Milosavljevic, S. Stefanovic, G. Rankovic, and S. M. Jankovic. 2020. "Cost-Utility of Tafenoquine vs. Primaquine for the Radical Cure (Prevention of Relapse) of Plasmodium Vivax Malaria." *Journal of Chemotherapy*, *32*(1): 21–29.

Kuecken, M., J. Thuilliez, and M.-A. Valfort. 2020. "Disease and Human Capital Accumulation: Evidence from the Roll Back Malaria Partnership in Africa." *The Economic Journal 131*(637): 2171–2202.

Kyaw, S. S., G. Delmas, T. L. Drake, O. Celhay, W. Pan-Ngum, S. Pukrittayakamee, *et al.* 2021. "Estimating the Programmatic Cost of Targeted Mass Drug Administration for Malaria in Myanmar." *BMC Public Health*, *21*(1): 826.

Ling, X. X., J. J. Jin, G. D. Zhu, W. M. Wang, Y. Y. Cao, M. M. Yang, *et al.* 2019. "Cost-Effectiveness Analysis of Malaria Rapid Diagnostic Tests: A Systematic Review." *Infectious Diseases of Poverty*, *8*(1): 104.

Luangasanatip, N., P. Khonputsa, C. Caillet, S. Vickers, S. Zambrzycki, F. M. Fernandez, *et al.* 2021. "Implementation of Field Detection Devices for Antimalarial Quality Screening in Lao PDR-A Cost-Effectiveness Analysis." *PLoS Neglected Tropical Diseases*, *15*(9): e0009539.

Lubogo, P., J. E. Lukyamuzi, D. Kyambadde, A. A. Komakech, F. E. Kitutu, and E. M. Mulogo. 2021. "Cost-Effectiveness Analysis of Integrated Community Case Management Delivery Models Utilizing Drug Sellers and Community Health Workers for Treatment of Under-Five Febrile Cases of Malaria, Pneumonia, Diarrhoea in Rural Uganda." *Malaria Journal*, *20*(1): 407.

Marathe, A., R. Shi, A. Mendez-Lopez, Z. Hu, B. Lewis, R. Rabinovich, *et al.* 2021. "Potential Impact of 5 Years of Ivermectin Mass Drug Administration on Malaria Outcomes in High Burden Countries." *BMJ Global Health*, *6*(11): e006424.

Morel, C. M., N. D. Thang, A. Erhart, N. X. Xa, K. Peeters Grietens, L. Xuan Hung, *et al.* 2013. "Cost-Effectiveness of Long-Lasting Insecticide-Treated Hammocks in Preventing Malaria in South-Central Vietnam." *PLoS One* *8*(3): e58205.

Mosha, J. F., M. A. Kulkarni, E. Lukole, N. S. Matowo, C. Pitt, L. A. Messenger, *et al.* 2022. "Effectiveness and Cost-Effectiveness Against Malaria of Three Types of Dual-Active-Ingredient Long-Lasting Insecticidal Nets (LLINS) Compared with Pyrethroid-Only LLINS in Tanzania: A Four-Arm, Cluster-Randomised Trial." *Lancet* *399*(10331): 1227–1241.

Mpangala, K. R., Y. A. Halasa-Rappel, M. S. Mohamed, R. C. Mnzava, K. J. Mkuza, P. E. Mangesho, *et al.* 2021. "On the Cost-Effectiveness of Insecticide-Treated Wall Liner and Indoor Residual Spraying as Additions to Insecticide Treated Bed Nets to Prevent Malaria: Findings from Cluster Randomized Trials in Tanzania." *BMC Public Health*, *21*(1): 1666.

Mtalimanja, M., K. S. Abasse, J. L. Mtalimanja, X. Z. Yuan, D. Wenwen, and W. Xu. 2022. "Economic Evaluation of Severe Malaria in Children Under 14 Years in Zambia." *Cost Effectiveness and Resource Allocation*, *20*(1): 4.

Mueller, D. H., V. Wiseman, D. Bakusa, K. Morgah, A. Daré, and P. Tchamdja. 2008. "Cost-Effectiveness Analysis of Insecticide-Treated Net Distribution as Part of the Togo Integrated Child Health Campaign." *Malaria Journal*, *7*: 73.

Nabyonga Orem, J., F. Mugisha, A. P. Okui, L. Musango, and J. M. Kirigia. 2013. "Health Care Seeking Patterns and Determinants of Out-Of-Pocket Expenditure for Malaria for the Children Under-Five in Uganda." *Malaria Journal*, *12*: 175.

Njau, J., S. P. Silal, A. Kollipara, K. Fox, R. Balawanth, A. Yuen, *et al.* 2021. "Investment Case for Malaria Elimination in South Africa: A Financing Model for Resource Mobilization to Accelerate Regional Malaria Elimination." *Malaria Journal*, *20*(1): 344.

Paintain, L., J. Hill, R. Ahmed, C. Umbu Reku Landuwulang, A. Ansariadi, J. Rini Poespoprodjo, *et al.* 2020. "Cost-Effectiveness of Intermittent Preventive Treatment with Dihydroartemisinin-Piperaquine Versus Single Screening and Treatment for The Control of Malaria in Pregnancy in Papua, Indonesia: A Provider Perspective Analysis from a Cluster-Randomised Trial." *The Lancet Global Health*, *8*(12): e1524–e1533.

Paudel, U. and K. P. Pant. 2020. "An Economic Analysis of Malaria Elimination Program in Nepal." *Heliyon 6* (5): e03886.

Phiri, M. D., R. S. McCann, A. N. Kabaghe, H. van den Berg, T. Malenga, S. Gowelo, *et al.* 2020. "Cost of Community-Led Larval Source Management and House Improvement for Malaria Control: A Cost Analysis Within a Cluster-Randomized Trial in A Rural District in Malawi." *Malaria Journal*, *20*(1): 268.

Por, I., S. Sovannaroth, A. Moran, L. Dysoley, S. Nguon, O. Bunthy, *et al.* 2020. "Cost-Effectiveness of Malaria Elimination in Sampov Loun Operational District, Cambodia." *MalariaWorld Journal*, *11*: 2.

RBM. 2015. *Action and Investment to Defeat Malaria 2016–2030: For a Malaria-Free World*. Geneva: World Health Organization on behalf of the Roll Back Malaria Partnership Secretariat. Available at https://endmalaria.org/sites/default/files/RBM_AIM_Report_0.pdf.

Renggli, S., R. Mandike, K. Kramer, F. Patrick, N. J. Brown, P. D. McElroy, *et al.* 2013. "Design, Implementation and Evaluation of a National Campaign to Deliver 18 Million Free Long-Lasting Insecticidal Nets to Uncovered Sleeping Spaces in Tanzania." *Malaria Journal*, *12*: 85.

Restrepo-Posada, D. C., J. A. Carmona-Fonseca, and J. A. Cardona-Arias. 2020a. "Systematic Review of Microeconomic Analysis of Pregnancy-Associated Malaria." *Heliyon*, *6*(7): e04558.

Restrepo-Posada, D. C., J. Carmona-Fonseca, and J. A. Cardona-Arias. 2020b. "Cost-Effectiveness of Rapid Diagnostic Tests, Compared to Microscopic Tests, for the Diagnosis and Treatment of Gestational Malaria in Colombia from an Institutional Perspective." *Malaria Journal*, *19*(1): 400.

Robinson, L.A., J. K. Hammitt, M. Cecchini, K. Chalkidou, K. Claxton, M. Cropper, P. Hoang-Vu Eozenou, D. de Ferranti, A. B. Deolalikar, F. Guanais, D. T. Jamison, S. Kwon, J. A. Lauer, L. O'Keeffe, D. Walker, D.

https://doi.org/10.1017/bca.2023.23 Published online by Cambridge University Press

Whittington, T. Wilkinson, D. Wilson, and B. Wong. 2019. *Reference Case Guidelines for Benefit-Cost Analysis in Global Health and Development*, funded by the Bill & Melinda Gates Foundation. Available at https://ssrn.com/abstract=4015886.

Sachs J. and P. Malaney. 2002. "The Economic and Social Burden of Malaria. *Nature*, *415*(6872): 680–685.

Sarker, A. R. and M. Sultana. 2020. "Cost-Effective Analysis of Childhood Malaria Vaccination in Endemic Hotspots of Bangladesh." *PLoS One 15*(5): e0233902.

Sauboin, C., L. A. Van Bellinghen, N. Van De Velde, and I Van Vlaenderen. 2019. "Economic Impact of Introducing the RTS,S Malaria Vaccine: Cost-Effectiveness and Budget Impact Analysis in 41 Countries." *MDM Policy & Practice*, *4*(2): 2381468319873324.

Shepard, D. S., J. U. Odumah, and S. T. Awolola. 2020. "Cost-Effectiveness of PBO versus Conventional Long-Lasting Insecticidal Bed Nets in Preventing Symptomatic Malaria in Nigeria: Results of a Pragmatic Randomized Trial." *American Journal of Tropical Medicine and Hygiene*, *104*(3): 979–986.

Shretta, R., A. L. Avanceña, and A. Hatefi. 2016. "The Economics of Malaria Control and Elimination: A Systematic Review." *Malaria Journal*, *15*(1): 593.

Silal, S. P. 2019. *METCAP Model (Version v1.0.2)*.

Silal, S. P., F. Little, K. I. Barnes, and L. J. White. 2014. "Towards Malaria Elimination in Mpumalanga, South Africa: A Population-Level Mathematical Modelling Approach." *Malaria Journal*, *13*: 297.

Silal, S., R. Shretta, O. Celhay, C. Mercado, S. Saralamba, R. J. Maude, *et al.* 2019. "Malaria Elimination Transmission and Costing in the Asia-Pacific: A Multi-Species Dynamic Transmission Model." *Wellcome Open Research*, *4*: 62.

Smith Paintain, L., E. Awini, S. Addei, V. Kukula, C. Nikoi, D. Sarpong, *et al.* 2014. "Evaluation of a Universal Long-Lasting Insecticidal Net (LLIN) Distribution Campaign in Ghana: Cost Effectiveness of Distribution and Hang-Up Activities." *Malaria Journal*, *13*: 71.

Sovi, A., C. Keita, Y. Sinaba, A. Dicko, I. Traore, M. B. M. Cisse, *et al.* 2020. "Anopheles Gambiae (S.L.) Exhibit High Intensity Pyrethroid Resistance Throughout Southern and Central Mali (2016–2018): PBO or Next Generation LLINs May Provide Greater Control." *Parasites & Vectors*, *13*(1): 239.

Sternberg, E.D., J. Cook, L. P. A. Alou, S. B. Assi, A. A. Koffi, D. T. Doudou, *et al.* 2021. "Impact and Cost-Effectiveness of a Lethal House Lure Against Malaria Transmission in Central Côte d'Ivoire: A Two-Arm, Cluster-Randomised Controlled Trial." *The Lancet*, *397*(10276): 805–815.

Stevens, W., V. Wiseman, J. Ortiz, and D. Chavasse. 2005. "The Costs and Effects of a Nationwide Insecticide-Treated Net Programme: The Case of Malawi." *Malaria Journal*, *4*: 22.

Sudathip, P., D. Kongkasuriyachai, R. Stelmach, D. Bisanzio, J. Sine, S. Sawang, *et al.* 2019. "The Investment Case for Malaria Elimination in Thailand: A Cost-Benefit Analysis." *American Journal of Tropical Medicine and Hygiene*, *100*(6): 1445–1453.

United Nations. 2015. *Sustainable Development Goals*. New York: United Nations Department of Economic and Social Affairs.

White, L. J., R. J. Maude, W. Pongtavornpinyo, S. Saralamba, R. Aguas, T. Van Effelterre, *et al.* 2009. "The Role of Simple Mathematical Models in Malaria Elimination Strategy Design." *Malaria Journal*, *8*: 212.

WHO. 2015. *Action and Investment to defeat Malaria 2016–2030*: For a Malaria-Free World: World Health Organization.

WHO. 2018. *High Burden to High Impact: A Targeted Malaria Response: Contract No. WHO/CDS/GMP/2018.25 Rev 1*. Geneva: World Health Organization.

WHO. 2022. *World Malaria Report*. Geneva: World Health Organization.

Winskill, P., P. G. Walker, R. E. Cibulskis, and A. C. Ghani. 2019. "Prioritizing the Scale-Up of Interventions for Malaria Control and Elimination." *Malaria Journal*, *18*(1): 122.

Worrall, E., V. Were, A. Matope, E. Gama, J. Olewe, D. Mwambi, *et al.* 2020. "Coverage Outcomes (Effects), Costs, Cost-Effectiveness, and Equity of Two Combinations of Long-Lasting Insecticidal Net (LLIN) Distribution Channels in Kenya: A Two-Arm Study Under Operational Conditions." *BMC Public Health*, *20*(1): 1870.

Yukich, J. P., S. Scates Digre, L. Boydens, E. Obi, N. Moran, *et al.* 2022. "Incremental Cost and Cost-Effectiveness of the Addition of Indoor Residual Spraying with Pirimiphos-Methyl in Sub-Saharan Africa Versus Standard Malaria Control: Results of Data Collection and Analysis in the Next Generation Indoor Residual Sprays (Ngenirs) Project, an Economic-Evaluation." *Malaria Journal*, *21*(1): 185.

Yukich, J. O., C. Scott, K. Silumbe, B. A. Larson, A. Bennett, T. P. Finn, *et al.* 2020. "Cost-Effectiveness of Focal Mass Drug Administration and Mass Drug Administration with Dihydroartemisinin-Piperaquine for Malaria

Prevention in Southern Province, Zambia: Results of a Community-Randomized Controlled Trial." *American Journal of Tropical Medicine and Hygiene*, *103*(2_Suppl): 46–53.
YukYuich, J. O., M. Zerom, T. Ghebremeskel, F. Tediosi, and C. Lengeler. 2009. "Costs and Cost-Effectiveness of Vector Control in Eritrea Using Insecticide-Treated Bed Nets." *Malaria Journal*, *8*: 51.

Appendix A: Literature review

Databases searched were MEDLINE via PubMed and Google Scholar. The following MeSH terms were used: "malaria" was combined with "control," "elimination," and "eradication." The following search terms were employed: "economics," "cost," "cost analysis," "economic evaluation," "economic burden," "cost-effectiveness," and "cost–benefit." Studies were classified based on their scope and were analyzed according to three major categories: cost-effectiveness of malaria control, cost-effectiveness of malaria elimination, and cost–benefit studies.

https://doi.org/10.1017/bca.2023.23 Published online by Cambridge University Press

Cost-effectiveness analyses of malaria control

Country or region	Study period	Study type	Perspective	Intervention	Control/ standard of care	Cost	Incremental ratio	Net benefit	Source
Multicountry	2007–2018	CEA: Systematic review	Provider	RDTs	Microscopy/ presumptive diagnosis	n/a	n/a	n/a	Ling *et al.* (2019)
	15 years	CEA + budget impact analysis Static Markov cohort model	Provider	RTS,S (child + infant doses)	No malaria vaccination	2015 US$ 697,345,540 for child vaccination 2015 US$ 729,228,602 for infant vaccination	ICER for child vaccination: US$ 200/DALY averted ICER for infant vaccination: US$ 225/DALY averted	n/a	Sauboin *et al.* (2019)
			Societal				ICER for child vaccination: US$ 187/DALY averted ICER for infant vaccination: US$ 212/DALY averted		
	2010–2017	Cost analysis and CEA: systematic review & meta-analysis	Provider Societal	Insecticide-treated nets	n/a	n/a	n/a	n/a	Winskill *et al.* (2019)
	Unspecified	CEA	Healthcare	Subsidized RDTs in retail sector	No retail sector RDT	US$ 2017	Cost per DALY averted in Nigeria: US$ 482 (5% PfPR); US$ 44 (PfPR)	n/a	Bath *et al.* (2020)

(*Continued*)

Continued

Country or region	Study period	Study type	Perspective	Intervention	Control/ standard of care	Cost	Incremental ratio	Net benefit	Source
		Decision-analytical model					Cost per DALY averted in Tanzania: US$ 115 (5% PfPR); US$ 45 (PfPR) Cost per DALY averted in Uganda: dominated (5% PfPR); dominated (PfPR)		
	1 year	CEA	Healthcare provider	3 sex-based treatments for *P. vivax*	Usual care	n/a	ICER Ethiopia: US$ 466 per DALY averted	n/a	Devine *et al.* (2020)
		Decision tree model					ICER Afghanistan: US$ 1,089 per DALY averted ICER Indonesia: US$ 4,443 per DALY averted ICER Vietnam: US$ 127 per DALY averted		
	Lifetime horizon	CEA	Healthcare provider	IPTp-DP	IPTp-SP	n/a	ICER US$ 8 per DALY averted	n/a	Fernandes *et al.* (2020)
		Decision tree model							
	5 years	Cost analysis	n/a		n/a		n/a	n/a	

(*Continued*)

Continued

Country or region	Study period	Study type	Perspective	Intervention	Control/ standard of care	Cost	Incremental ratio	Net benefit	Source
				Rapid reporting (RR)		2014 US$ cost per capita: US$ 0.18 for RR			Galactionova *et al.* (2020)
				Reactive case detection (RACD)		Cost per capita: US$ 0.75 for RACD			
				MDA		Cost per capita: US$ 4.28 for MDA			
				IRS		Cost per capita: US$ 1.79 for IRS			
	1990–2018	CEA: Systematic review	n/a	Pregnancy-associated malaria	n/a	n/a	ACER: US$ 2 per DALY averted in IPTp-SP	n/a	Restrepo-Posada *et al.* (2020a))
							ACER: US$ 14.2 per DALY averted in IPTp-SP in pregnant women with HIV		
	Unspecified	Cost analysis	Government	RTS,S/ASO1E	n/a	2017 US$ Incremental financial costs per fully vaccinated child	n/a	n/a	Baral *et al.* (2021)

(*Continued*)

Continued

Country or region	Study period	Study type	Perspective	Intervention	Control/ standard of care	Cost	Incremental ratio	Net benefit	Source
						US$ 11.50 (Ghana) to US$ 13.69 (Malawi)			
	2016	CEA and cost-savings analysis	Programmatic	SMC	n/a	2016 US$ Economic cost of 4 monthly SMC per child: US$ 3.63	US$ 18.66 to US$ 78.91 per DALY averted	n/a	Gilmartin *et al.* (2021)
	2000–2020	CEA: Systematic review	Provider	Mass screen and treat	No mass screen and treat	n/a	varied	n/a	Kim *et al.* (2021)
	2023–2027	CEA	n/a	MDA with Ivermectin	n/a	US$ 112.1 million – US$ 597.2 million	US$ 1,460 – US$ 4,374: Cost per death averted	n/a	Marathe *et al.* (2021)
	2017	CEA	Program	IRS + standard malaria control interventions + LLINs	Standard malaria control	interventions	US$ cost per person targeted US$ 5.33	US$ 48 – US$ 1,593 per DALY averted	n/a
Yukich *et al.* (2022)									
Africa									
Cote d'Ivoire	2016–2019	CEA	Societal	Screening + Eave Tubes+ LLINs	LLINs only	Economic cost per house covered US $ 239.46	US$ 210.29 per year per DALY averted	n/a	Sternberg *et al.* (2021)

(*Continued*)

Continued

Country or region	Study period	Study type	Perspective	Intervention	Control/ standard of care	Cost	Incremental ratio	Net benefit	Source
			Provider			Economic cost per house covered US$ 215.38	US$ 192.30 per year per DALY averted		
Ethiopia	Unspecified	Extended CEA	n/a	ACT	n/a	2016 US$ 5.7 million	358 deaths averted; US$ 1,560,000 OOP expenditures reduced		Assebe *et al.* (2020)
		Static model		LLIN		US$ 16.5 million	188 deaths averted; US$ 13,000 OOP expenditures reduced		
				IRS		US$ 32.6 million	107 deaths averted; US$ 3,700 OOP expenditures reduced		
				Vaccine		US$ 5.1 million	38 deaths averted; US$ 2,800 OOP expenditures reduced		
Ghana	2018	Cost-savings analysis (CEA included) Transmission model	n/a	Partial IRS	Full IRS	Cost per person of partial IRS US$ 4.94	US$ 0.87 per clinical case averted	n/a	Coleman *et al.* (2021)
Kenya	Unspecified	Cost analysis and CEA	n/a	LLIN distribution channels A	LLIN distribution channels B	2015 US$ Unit cost US$ 10.56 LLIN	US$ 86.44	n/a	Worrall *et al.* (2020)

(*Continued*)

Continued

Country or region	Study period	Study type	Perspective	Intervention	Control/ standard of care	Cost	Incremental ratio	Net benefit	Source
						distribution channel A Unit cost US$ 7.17 LLIN distribution channel B	US$ 69.20		
Malawi	3 years	CEA	n/a	RTS,S + Bed nets	Control vaccine	n/a	RTS,S: US$ 23.86 per case averted RTS,S + bed net: US$ 38.91 per case averted	n/a	Bell *et al.* (2020)
Malawi	2014–2019	Cost analysis	Program	NMCP interventions + HI	NMCP	interventions	2017 US$ Incremental economic cost US$ 25.06 – US$ 33.44 per person per year	n/a	n/a
Phiri *et al.* (2020)									
				NMCP interventions + LSM					
				NMCP interventions + HI + LSM					
Mali	2014	CEA	Provider	SMC	n/a	2016 US$ economic cost per child	ICER: US$ 144 per DALY averted	n/a	Diawara *et al.* (2021)

(*Continued*)

Continued

Country or region	Study period	Study type	Perspective	Intervention	Control/ standard of care	Cost	Incremental ratio	Net benefit	Source
						receiving SMC: US$ 3.43			
		Transmission model				Economic cost per child fully adherent: US$ 6.38			
Mozambique	2015	CEA	Provider	LLIN (new delivery model)	LLIN (standard delivery model)	Financial cost Intervention: US$ 231,237.30	ICER per LLIN: US$ 0.68	Positive	Arroz *et al.* (2019)
						Financial cost Control: US$ 174,790.14	ICER per household UC: US$ 2.24		
							ACER per LLIN: US$ 0.76 intervention		
							ACER per LLIN: US$ 0.8 control		
							ACER for HH achieving UC: US$ 2.38 intervention		
							ACER for HH achieving UC: US$ 2.43 control		
Mozambique	3 years	Cost analysis and CEA	Project	implementer	MDA + intensified malaria control	Routine malaria control activities	2015 US$ 4.83 million	ICER US$ 987	n/a

(*Continued*)

Continued

Country or region	Study period	Study type	Perspective	Intervention	Control/ standard of care	Cost	Incremental ratio	Net benefit	Source
Cirera *et al.* (2020)									
Mozambique	2016–2018	Cost analysis and CEA	Provider	IRS + LLINs	LLINs alone	IRS cost per person protected US$ 8.26	ICER in under 5 cohort: US$ 400 per DALY averted ICER in all-age cohort: US $ 1,860 per DALY averted	n/a	Alonso *et al.* (2021)
Mozambique	2014	Cost analysis	Provider	IRS	n/a	2014 US$ Economic cost per household sprayed: US$ 16.35 Economic cost per person protected: US$ 4.09	n/a	n/a	Canana (2021)
Nigeria	2010–2014	CEA	Prevention Health system	PBO	Conventional LLINs	2019 US$	ICER US$ 11 per DALY averted ICER: PBO nets were cost-saving compared to conventional LLINs	n/a	Shepard *et al.* (2020)
Nigeria	Unspecified	Extended CEA	n/a		n/a	2020 US$ 254.4 million	76 deaths averted per US$ 1 million invested	n/a	Dasgupta *et al.* (2022)

(*Continued*)

Continued

Country or region	Study period	Study type	Perspective	Intervention	Control/ standard of care	Cost	Incremental ratio	Net benefit	Source
				Subsidies of direct and indirect costs					
		Decision tree model							
South Africa	2015–2017	CEA	Health services	Reactive, targeted IRS	Standard IRS	2017 US$ Economic cost US$ 88,258 per 100,000 population for targeted IRS	ICER: US$ 7,845 saved by targeted IRS for each additional DALY incurred	n/a	Bath *et al.* (2021)
Tanzania	2015–2016	CEA	n/a	ITWL + LLINs	IRS + LLINs	2019 US$ ITWL cost per person per year US$ 10.11	ICER: US$ 490 per DALY averted	n/a	Mpangala *et al.* (2021)
Tanzania	2-year time horizon	CEA	Provider/ Donor	Three dual-active-ingredient LLINs	Pyrethroid-only LLINs	Cost per net: US$ 2.07 – US$ 3.68	Chlorfenapyr: US$ 19 more per DALY averted to public providers (or US$ 28 more to donors); PBO: US$ 130 (136 to donors) more per DALY averted	n/a	Mosha *et al.* (2022)
			Household						
Uganda	2013–2015	CEA	Societal	iCCM interventions	iCCM	Societal interventions via CHWs	2018 US$ Cost per 100 treated under 5	ICER: US$ 33.86 per appropriately	n/a

(*Continued*)

Continued

Country or region	Study period	Study type	Perspective	Intervention	Control/ standard of care	Cost	Incremental ratio	Net benefit	Source
				via drug sellers			children: US$ 298.42 for iCCM drug seller arm	treated under 5 patient	
Lubogo *et al.* (2021)									
Zambia	Unspecified	CEA	Provider	SoC + Focal MDA	Standard of care malaria	interventions	2015 US$ 2 million total cost	ICER: US$ 6,353 per case averted for fMDA	n/a
Yukich *et al.* (2020)									
				SoC + MDA			ICER: US$ 1,872 per case averted for MDA		
Zambia	14-year time horizon	CEA	Healthcare provider	Artesunate	Quinine	2020 US$ 23.45	US$ 91 per death averted	n/a	Mtalimanja *et al.* (2022)
		Markov model							
Americas									
Brazil	2020	CEA	Public health system	Real-life quantitative G6PD screening	Routine strategy	2020 US$ 7.86	US$ 495 per hospitalization avoided	n/a	Brito-Sousa *et al.* (2022)
		Decision tree							

(*Continued*)

Continued

Country or region	Study period	Study type	Perspective	Intervention	Control/ standard of care	Cost	Incremental ratio	Net benefit	Source
Colombia	Less than 1 year	CEA	Institutional	RDTs	Microscopy	US$ 66,936 for RDTs	ICER: US$ 101.2 per DALY averted	n/a	Restrepo-Posada *et al.* (2020b)
		Decision tree				US$ 50,838 for Microscopy			
Asia									
Bangladesh	5-year time horizon	CEA	Health system	RTS,S/AS01	Usual care	Cost per fully vaccinated child: US$ 0.84	ICER: US$ 2,629 per DALY averted from the health system perspective	n/a	Sarker and Sultana (2020)
		Decision model	Societal				ICER: US$ 2,583 per DALY averted from the societal perspective		
Indonesia	2013–2016	CEA	Provider	IPTp-DP	Screening and treatment DP	2016 US$ Cost per screening and treatment if positive: US$ 4.69	ACER: US$ 53 per DALY averted	n/a	Paintain *et al.* (2020)
		Decision tree model				Cost per screening and treatment if negative: US$ 1.92			

(*Continued*)

Continued

Country or region	Study period	Study type	Perspective	Intervention	Control/ standard of care	Cost	Incremental ratio	Net benefit	Source
						Cost per administration of IPTp: US$ 2.76			
Lao DPR	5-year time horizon	CEA + Budget impact analysis	Provider	Six portable screening devices	Visual inspections alone	2017 US$ 0.04 – US $ 3.06 unit cost per sample	ICER high prevalence scenario: US$ 391–US $ 1,514 per DALY averted ICER low prevalence scenario: US$ 436 – US $ 4,496 per DALY averted	n/a	Luangasanatip *et al.* (2021)
Myanmar	2015–2016	CEA	Provider	Topical repellent	No repellent	2015 US$ 76,138	US$ 256 per PCR-detected infection averted	n/a	Agius *et al.* (2020)
Myanmar	1-year time horizon	CEA + Budget impact analysis Decision tree model	Payer	G6PD diagnosis test + Primaquine treatment	Unsupervised Primaquine treatment	2020 US$ 811.69 – US$ 1,838.5	ICER: US$ 96.72 unsupervised test; US$ 184.86 supervised test	n/a	Aung *et al.* (2022)

Cost-effectiveness analyses of malaria elimination

Country or region	Study period	Study type	Perspective	Intervention	Control/standard of care	Cost	Cost-effectiveness ratio	Net benefit	Source
Africa									
Senegal	2014–2015	Cost	n/a	Mass test and treat (MTAT) + PECADOM ++	PECADOM++	US$ 14.3 per person MTAT	n/a	n/a	Conner *et al.* (2020)
					Case investigation				
Asia									
Cambodia	2015–2018	CEA	Provider	Malaria elimination program		US$ 883,096	ICER US$ 28 per Pf or Pv/Pf case averted	n/a	Por *et al.* (2020)
		Decision tree model	Societal			US$ 926,000			
China	2018–2019	CEA	Societal	RDT	RDT + microscopy	2018 US$ 4.47 million RDT	ICER: US$ 69,856.70	n/a	Du *et al.* (2020)
		Decision tree model		Microscopy		US$ 3.63 million Microscopy	ICER: US$ 49,514.29		
						US$ 2.75 million RDT + Microscopy			
Myanmar	n/a	Cost analysis	Program-matic	MDA	n/a	US$ 2.5 per person reached	n/a	n/a	Kyaw *et al.* (2021)
Europe									

(*Continued*)

Continued

Country or region	Study period	Study type	Perspective	Intervention	Control/standard of care	Cost	Cost-effectiveness ratio	Net benefit	Source
Serbia	10 years	Cost utility	Healthcare provider	Tafenoquine	Primaquine	Cost per patient TQ: 58,474.97 +/− 1,575.16 RSD	ICER: 54,162.52 +/− 330,452.21 RSD	20,713.84 +/− 7,167 RSD	Kostic *et al.* (2020)
		Markov model				Cost per patient PQ: 65,903.05 +/− 1,769.69 RSD			
	4 years					Cost per patient TQ: 29,376.64 +/− 1,341.37 RSD	ICER: 79,673.43 +/− 403,380.79 RSD	12,846.31 +/− 4,936.29 RSD	
						Cost per patient PQ: 35,039.13 +/− 1,614.82 RSD			

Cost–benefit analyses

Country or setting	Study period	Focus (control or elimination)	Benefit–cost ratio	Source
Africa				
South Africa	2018–2030	Elimination	7.42 (Total ROI)	Njau *et al.* (2021)
Asia				
Nepal	2016	Elimination	1.58	Paudel and Pant (2020)
South Korea	2014–2018	Elimination	2.5	Kim *et al.* (2021b)
Thailand	2017–2036	Elimination	Cost-saving (BCR >1)	Sudathip *et al.* (2019)

https://doi.org/10.1017/bca.2023.23 Published online by Cambridge University Press

Appendix B: Cost assumptions (US$ 2021).

Cost	Source	Angola	Benin	Burkina Faso	Burundi	Cameroon	CAR	Chad	Cote d'Ivoire	DRC	Ethiopia	Ghana	Guinea	Kenya	Liberia	Madagas-car
Cost per LLIN	PMI Technical guidance 2021 (56)	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68
Average cost of each CHW per year	Country average	744	1.32	0.36	372	0.72	0.72	0.72	1.32	0.72	1,260	720	516	1,884	720	372
Unit cost RDT	Global Fund	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Unit cost slide	Countries	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Cost per person protected by IRS	PMI IRS Country programs: comparative cost analysis 2020, 2021	7.04	3.70	6.12	n/a	n/a	n/a	n/a	n/a	n/a	6.40	5.46	n/a	4.59	7.04	5.39
Average cost of drug per Pf case	Global Fund	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Inpatients average	Global Fund	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76

(*Continued*)

Continued

Cost	Source	Angola	Benin	Burkina Faso	Burundi	Cameroon	CAR	Chad	Cote d'Ivoire	DRC	Ethiopia	Ghana	Guinea	Kenya	Liberia	Madagas-car
cost of drug per case																
Inpatients average cost of treatment per case	WHO-CHOICE estimates of cost for inpatient and outpatient health service delivery: Results in 2008 International Dollars (PPP Int$)	54.44	11.61	10.60	2.28	18.40	5.04	10.17	12.97	1.81	6.07	11.33	7.68	12.14	2.33	7.63
Outpatients average cost of treatment per case	WHO-CHOICE estimates of cost for inpatient and outpatient health service delivery: Results in 2008 International Dollars (PPP Int$)	10.55	3.44	3.22	1.05	4.80	1.88	3.12	3.73	0.89	2.15	3.38	2.55	3.55	1.07	2.53
Cost per person enrolled in SMC	ACCESS SMC partnership 2020	n/a	n/a	3.05	n/a	3.05	n/a	3.05	n/a	n/a	n/a	3.05	3.05	n/a	n/a	n/a
Cost per drug for SMC	Global Fund	n/a	n/a	1.4	n/a	1.4	n/a	1.4	n/a	n/a	n/a	1.4	1.4	n/a	n/a	n/a

(*Continued*)

Continued

Cost	Source	Angola	Benin	Burkina Faso	Burundi	Cameroon	CAR	Chad	Cote d'Ivoire	DRC	Ethiopia	Ghana	Guinea	Kenya	Liberia	Madagas-car
Cost per person enrolled in IPTp	Global Fund	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Cost per drug for IPTp	Global Fund	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Average cost of training per capita	Country documents and proxies	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Average cost IEC per capita	Country documents and proxies	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

Cost	Source	Malawi	Mali	Mozam-bique	Niger	Nigeria	Rwanda	Senegal	Sierra Leone	South Sudan	Sudan	Tanzania	Togo	Uganda	Zambia
Cost per LLIN	PMI Technical guidance 2019	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68
Average cost per CHW per year	Country documents and proxies	372	0.72	372	0.72	1.32	372	156	156	1,884	1,884	1,884	156	372	372
Unit cost RDT	Global Fund	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Unit cost slide	Country documents and proxies	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Cost per person protected by IRS	PMI IRS country programs: comparative cost analysis 2020, 2021	n/a	9.03	5.13	n/a	7.04	5.71	7.55	n/a	n/a	n/a	4.17	n/a	3.45	2.87
Average cost of drug per Pf case	Global Fund and others	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Inpatients average cost of drug per case	Global Fund and others	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76
Inpatients average cost of treatment per case	WHO-CHOICE estimates of cost for inpatient and outpatient health service delivery: Results in 2008 International Dollars (PPP Int US$)	5.25	8.47	5.82	4.58	18.16	7.90	14.44	5.37	17.68	17.68	9.51	8.96	10.17	10.33
Outpatients average cost of treatment per case	WHO-CHOICE estimates of cost for inpatient and	1.93	2.74	2.08	1.75	4.76	2.60	4.03	1.97	4.67	4.67	2.98	2.85	3.12	3.16

(*Continued*)

Continued

Cost	Source	Malawi	Mali	Mozam-bique	Niger	Nigeria	Rwanda	Senegal	Sierra Leone	South Sudan	Sudan	Tanzania	Togo	Uganda	Zambia
	outpatient health service delivery: Results in 2008 International Dollars (PPP Int$)														
Cost per person enrolled in SMC	ACCESS SMC partnership 2020	n/a	3.05	n/a	3.05	3.05	n/a	3.05	n/a	n/a	n/a	n/a	3.05	n/a	n/a
Cost per drug for SMC	Country documents and proxies	n/a	1.40	n/a	1.40	1.40	n/a	1.40	n/a	n/a	n/a	n/a	1.40	n/a	n/a
Cost per person enrolled in IPTp	Country documents and proxies	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Cost per drug for IPTp	Country documents and proxies	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Average cost of surveillance per capita	Country documents and proxies	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Average cost of training per capita	Country documents and proxies	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Average cost IEC per capita	Country documents and proxies	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

Appendix C: Cost–benefit ratios by country for the incremental investment of raising LLIN and SBCC coverage by 10 percentage points from 2023–2030.

Angola	15
Benin	51
Burkina Faso	40
Burundi	18
Cameroon	25
CAR	20
Chad	82
Cote d'Ivoire	30
DRC	128
Ethiopia	10
Ghana	36
Guinea	17
Kenya	45
Liberia	24
Madagascar	11
Malawi	11
Mali	34
Mozambique	28
Niger	34
Nigeria	87
Rwanda	9
Senegal	33
Sierra Leone	16
South Sudan	19
Sudan	9
Tanzania	64
Togo	26
Uganda	35
Zambia	23

Cite this article: Shretta, R, and R Ngwafor Anye. 2023. "An Investment Case for the Scale-up and Use of Insecticide-Treated Nets Halfway into the SDG Targets." *Journal of Benefit-Cost Analysis* 14: 16–54, doi:10.1017/bca.2023.23