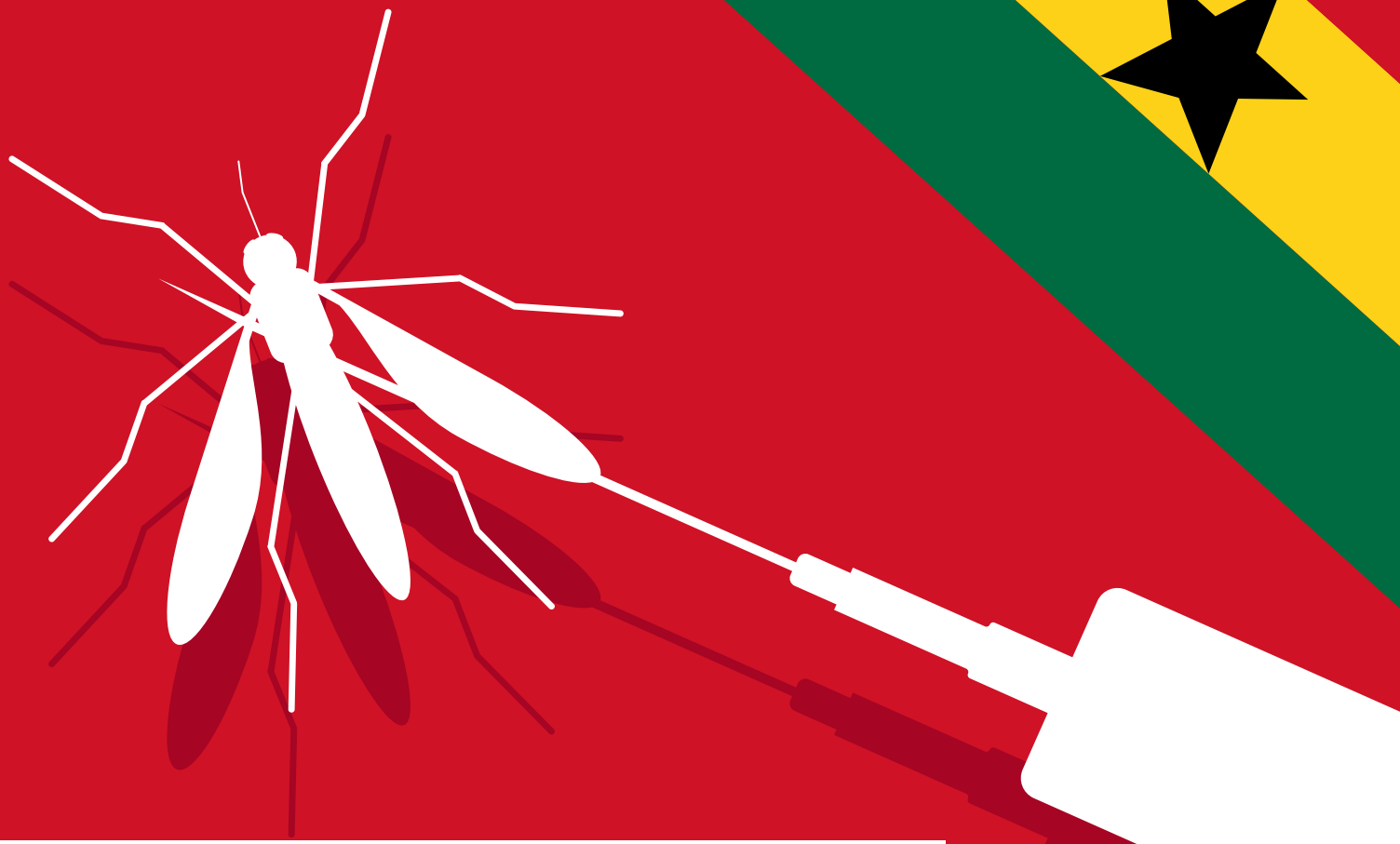

COST-BENEFIT ANALYSIS OF SELECTED MALARIA INTERVENTIONS IN GHANA

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Cost Benefit Analysis of Selected Malaria Interventions in Ghana

Ghana Priorities[1]

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Academic Abstract

Malaria represents the largest cause of death and morbidity in Ghana with the incidence being as high as one clinical case for every five people per year. Besides leading to significant loss of life, it also imposes significant demands on the health system and reduces economic growth. This paper evaluates the costs and benefits associated with three key malaria interventions in Ghana; continuous and sustained LLIN distribution, seasonal malaria chemoprevention (SMC) in Northern Ghana and increase in testing and treatment of suspected malaria cases which present at health facilities to near universal levels. The paper draws upon a recently developed malaria transmission model for Ghana. Our analysis shows that a continuous bed net distribution intervention that reaches and sustains 90 per cent coverage of households, up from current coverage of 56 per cent, has the potential to avoid 40,390 deaths between now and 2030, leading to benefits 44 times the cost. Given the large benefits relative to costs and the strength of evidence, this intervention should strongly be considered by Ghanaian policy makers for further scale up. Additionally, increasing coverage of rapid diagnostic testing of suspected malaria cases in health facilities has the potential to be an efficient use of resources, avoiding 24,770 deaths to 2030 and generating a benefit-cost ratio (BCR) of 134. However, this analysis requires reaching nearly all of the remaining 10% of suspected malaria cases that present at health facilities, and there is significant uncertainty around the feasibility and appropriate cost profile for reaching this group. The analysis of scaling up SMC generates a BCR of 14, a lower benefit-cost ratio than either of the other two interventions though still large relative to other potential uses of funds identified in the Ghana Priorities series.

Key Words: Cost benefit analysis, Ghana, lives saved, malaria intervention, malaria transmission model.

Policy Abstract

Key Takeaways

- Ghanaian policy makers should strongly consider scaling up LLIN distribution in the country. Distributing 2m to 2.5m more bed nets per year, so that household coverage of LLIN is sustained at 90 per cent will avoid 40,390 deaths between now and 2030. Because providing bed nets is relatively inexpensive - around GH¢ 25 per net distributed – the intervention will deliver benefits worth 44 cedis per cedi spent. The evidence for this is very strong.
- Increasing efforts to ensure the last 10 per cent of suspected malaria cases which present at health facilities (on average 36,150 per year) are tested could also be highly cost-effective with a benefit-to-cost ratio (BCR) of 134. Our analysis suggests it would avoid 24,770 deaths between now and 2030, mostly from properly detecting and treating malaria early, which minimizes the risk of severe cases. The evidence for this is limited since there is substantial uncertainty around the feasibility and costs of this intervention.
- Increasing coverage of seasonal malaria chemoprevention (SMC) to 90 per cent of children in the Guinea Savannah region of Ghana (on average 434,000 more children per year) will avoid 3,265 deaths between now and 2030. The BCR of this intervention is 14.

The Problem

According to the Global Burden of Disease (GBD), malaria represents the largest cause of death and morbidity in the country as measured by disability adjusted life years (DALYs) (IHME, 2019). In 2017, the disease was responsible for around 19,000 deaths, almost as much as the combined death toll from HIV/AIDs and tuberculosis (IHME, 2019). The GBD estimates 5.9m incident cases per year or equivalent to one case for every five people (IHME, 2019). Malaria puts a significant strain on the health system with a third of all outpatient department (OPD) visits being for suspected cases of malaria (Ghana Health Service, 2019).

Malaria also takes a large toll on the economy. On average, 13.5 per cent of individuals in the prime working age range of 15-49 contract malaria annually (IHME, 2019). If each case of malaria takes five days to fully recover, a simple estimation suggests 2 per cent of all potential working days are lost to malaria. A survey of 62 firms in the Greater Accra, Ashanti and

Western Regions showed 40 per cent of all lost work-days were due to malaria (Nonvingon et al., 2016). An older study indicated that a 1 per cent increase in malaria morbidity reduced economic growth in the country by 0.41 per cent per annum (Asante and Asenso-Okyere, 2003). UNICEF (2007) estimated the annual economic burden of malaria be 1.0% to 2.0% of gross domestic product (GDP) in Ghana. Sachs and Malaney (2002) opine that malaria endemic regions tend to have an average growth per capita GDP of 0.4% per year compared to 2.3% average per capita GDP per year for non-endemic regions.

Intervention 1: Distribute and sustain 90 per cent coverage of LLIN

Overview

Despite substantial successes achieved in malaria prevention in Ghana, the country is yet to achieve the NSP goal of reducing malaria burden by 75% by 2020. Since 2002, the government of Ghana has prioritized ensuring access to and increasing use of LLINs to reduce malaria-associated morbidity and mortality. One of the key objectives of the National Malaria Control Programme (NMCP) is to reach and sustain universal LLIN coverage, which is defined as one LLIN for every two persons.

The bed nets distribution intervention targets 90 per cent of households in Ghana. Given a baseline population of 31 million, 3 million bed nets distributed and 56 per cent of the population effectively covered by bed nets in 2018, it is envisaged that the intervention will increase the number of bed nets distributed via continuous distribution by 2m to 2.5m per year, eventually reaching the 90 per cent target in 2021 and sustaining this level indefinitely.

Implementation Considerations

To achieve this target LLIN coverage would require a 70% increase in LLIN distribution over current levels. This would require extra funding for the National Malaria Control Program (NMCP) of GH¢ 45m initially rising to GH¢ 73m by 2030 (in 2018 GH¢). This would represent a non-trivial expansion of current program activities by the NMCP.

Costs and Benefits

Costs

Costs estimated represent the full procurement and distribution costs of bed nets, based on evidence of large-scale LLIN distribution in Ghana. Distributing 2 to 2.5 million extra bed nets would cost GH¢ 45m initially and rises to GH¢ 73m by 2030. The total net present cost of this intervention between 2018 and 2030 is GH¢ 442m at an 8% discount rate.

Benefits

Epidemiological modelling indicates that scaling up mass distribution of LLINs and rapid diagnostic testing have very large absolute impacts on burden and deaths avoided. Increasing coverage of LLINs from 56 per cent to 90 per cent will avoid 12.9m cases of uncomplicated malaria, 696,000 cases of severe malaria and 40,390 deaths between 2018 and 2030. The study estimates avoided morbidity benefits of GH¢ 9 million, mortality avoided benefits of GH¢ 139 million in 2018, with benefits expected to increase to GH¢ 230 million and GH¢ 4,803 million respectively in 2030.

Intervention 2: Seasonal Malaria Chemoprevention to 90 per cent of children in the Guinea Savannah zone

Overview

Despite the many interventions in place, the burden of malaria remains high and new preventive and control measures are of necessity to augment the existing measures. Seasonal malaria chemoprevention (SMC), formerly known as intermittent preventive treatment in children (IPTc), has been identified as a potentially effective strategy in areas with a short malaria transmission season. The intervention considers treatment with SP +AQ for four rounds (four months) through the rainy season (July to Oct) for children 3-59 months old from current coverage levels of 22 per cent of children (approximately 100,000 children) to 90 per cent (approximately 500-600,000 children).

Implementation Considerations

Expansion of SMC to these levels would require significant planning and human resources. The Northern region of Ghana is large and in some areas sparsely populated with poor road infrastructure. Expanding to these levels would require GH¢ 17 million initially rising to GH¢ 29 million by 2030 (2018 GH¢).

Costs and Benefits

Costs

The costs for this intervention are drawn from a study in Northern Ghana which suggest a unit cost of GH¢ 43 per child per course of SMC. For a targeted increase in coverage to 90 per cent, the total cost of SMC is therefore GH¢ 17 million initially rising to GH¢ 29 million by 2030 (2018 GH¢). The present value of this is GH¢ 167 million at a 8% discount rate.

Benefits

The intervention would avoid 964,000 uncomplicated cases, 72,400 severe cases and 3,265 deaths between 2018 and 2030. This is valued at GH¢ 116 million initially rising to GH¢ 496 million by 2030 (2018 GH¢). The present value of this is GH¢ 2,303 million at an 8% discount rate.

Intervention 3: (Near) universal testing and treatment of suspected cases presenting at heath facilities

Overview

The WHO recommends diagnostic testing to confirm malaria before providing anti-malarial treatment to suspected cases. This recommendation aims to limit indiscriminate anti-malarial use, and is premised on the emerging parasitic resistance to anti-malarials; the quest to have clinicians find treatments that are appropriate for non-malaria febrile illness; declining malaria transmission in previously high transmission areas; and increased availability of diagnostics, notably, rapid diagnostic tests (RDTs) for malaria in resource-limited environments.

Currently, testing coverage of suspected malaria cases in health facilities is 90 per cent, and the analysis investigates movement towards (near) universal testing as per NMCP targets. The specific intervention analyses increasing the probability of being tested and diagnosed for clinical malaria infection for suspected cases presenting at health facilities before treatment of all confirmed cases of clinical malaria across Ghana - a 10 per cent increase (to almost 100 per cent coverage) in the probability of being tested with an RDT or by microscopy in all three zones.

Implementation Considerations

To initiate this intervention would require a number of steps. These include i) training, to ensure health facility staff use tests and are aware of appropriate protocols for the use of tests ii)

improvements in availability of RDTs or microscopy testing equipment, including minimizing stock outs, particularly in remote areas and iii) monitoring and evaluation to detect areas of deficiency and constraints to reaching near universal coverage.

Costs and Benefits

Costs

A previous study indicates that the average cost of implementing RDT (training, supervision and the provision of RDT itself) in a standard setting is GH¢ 24.9 per suspected patient in 2018 values. However, due to the envisioned difficulty in ensuring test-based diagnosis in the remaining 10 per cent of suspected malaria cases, this paper suggests a 'last-mile' premium of 10x, i.e. reaching the last 10 per cent will cost ten times the average cost of reaching the first 90 per cent – a value of GH¢**249** per suspected case. Under this assumption, the costs are equal to GH¢7 million in the first year, increasing to GH¢ 14 million by 2030. The total costs are GH¢ 87 million between 2018 and 2030 at an 8% discount rate.

Benefits

By properly diagnosing malaria using tests and treating early, the intervention will avoid a large amount of severe malaria cases - 434,780 between 2018 and 2030. In turn, this is expected to avoid 24,700 deaths over the same time period. There will also be a modest reduction in uncomplicated malaria cases (17,330 in total to 2030) well as some cost savings in drugs and time from improved diagnosis equal to GH¢ 17 per suspected malaria case. Overall the benefits are GH¢ 211 million in the first year, rising to GH¢ 2,689 million by 2030. The total present value of benefits over the time period are GH¢ 11,595 million of which 99% are attributable to avoided mortality.

BCR Summary Table

Intervention	Discount Rate	Benefit GHS m	Cost GHS m	BCR	Quality of Evidence
Distribute and sustain 90 per cent coverage of LLIN	8%	19,359	442	44	Very Strong
Seasonal Malaria Chemoprevention to 90 per cent of children in the Guinea Savannah zone	8%	2,303	167	14	Medium
Near universal coverage of testing and treatment at health facilities	8%	11,595	87	134	Limited

1. Introduction

The Ghanaian health system first began combating malaria in the 1950s with the adoption of strategies such as Indoor Residual Spraying (IRS) against adult mosquitoes, mass chemoprophylaxis with Pyrimethamine medicated salt and basic sanitation practices to improve drainage systems (Ghana Health Service, 2019). Decades on, much has changed in the approaches used to combat the disease, and despite significant recent progress, malaria remains a major public health concern.

According to the Global Burden of Disease (GBD), malaria represents the largest cause of death and morbidity in the country as measured by disability adjusted life years (DALYs) (IHME, 2019). In 2017, the disease was responsible for around 19,000 deaths, almost as much as the combined death toll from HIV/AIDs and tuberculosis (IHME, 2019). The GBD estimates 5.9m incident cases per year or equivalent to one episode for every five people (IHME, 2019). Malaria puts a significant strain on the health system with a third of all outpatient department (OPD) visits being for suspected cases of malaria (Ghana Health Service, 2018).

Malaria also takes a large toll on the economy. On average, 13.5 per cent of individuals in the prime working age range of 15-49 will contract malaria annually (IHME, 2019). If each case of malaria takes five days to fully recover, a simple estimation suggests 2 per cent of all potential working days may be lost to malaria. A survey of 62 firms in the Greater Accra, Ashanti and Western Regions showed 40 per cent of all lost work days were attributable to malaria morbidity (Nonvingon et al., 2016a). An older study indicated that a 1 per cent increase in malaria morbidity reduced economic growth in the country by 0.41per cent (Asante and Asenso-Okyere, 2003). The National Malaria Control Program (NMCP) is the body in Ghana tasked with addressing the burden of malaria. Its current goal is to reduce malaria burden by 75 per cent by 2020, compared to 2012. To this end the NMCP has set a series of strategic goals including providing protective measures to 80 per cent of the population and testing 100 per cent of suspected cases of malaria at health facilities (Ghana Health Service, 2018). The NMCP has made significant progress in the fight against malaria and from 2012 to 2017 the Global Burden of Disease estimates a 40 per cent reduction in new cases of infection annually (IHME, 2019). Data captured at Ghanaian health facilities paints a mixed picture with the number of confirmed cases at health facilities remaining more or less unchanged since 2012, while the number of deaths associated with inpatient admissions has fallen from 2799 in 2012

to only 599 in 2017 (~80 per cent reduction). However, this data is an incomplete representation of malaria in Ghana because not all malaria cases are reported in health facilities.

A key question for NMCP and Ghana in general, is how to most effectively make use of limited resources to combat what is arguably the country's largest health concern. This paper seeks to provide input to this important question by conducting cost-benefit analyses of scaling up three prominent strategies to address malaria: continuous distribution of long-lasting insecticide treated bed nets (LLIN), seasonal malaria chemoprevention (SMC) and rapid diagnostic testing (RDT) at health facilities.

We utilize a recently developed malaria transmission model for Ghana to estimate the impacts of these interventions (Awine, 2019). The model is the first comprehensive malaria transmission model to incorporate spatial and temporal variation in malaria burden and climate in Ghana (Awine et al. 2018). This paper therefore adds valuable, and potentially more accurate, insights into the relative efficiency of different malaria control policies in the country.

Additionally, this study is one of very few cost-benefit analyses of malaria interventions conducted to inform current malaria policy.[2] A review of economic analyses of malaria interventions revealed only ten published cost-benefit analyses up to September 2014, with most of these focusing on periods during the 1960s and 1970s, and only three with analyses focusing on the period from 2000 and beyond (Shretta, Avanceña and Hatefi, 2016). Since 2014, several more malaria cost-benefit analyses have been conducted, including under the auspices of the Copenhagen Consensus Center, but to the best of our knowledge these have typically been at a global level or couched as returns to investment in tuberculosis, malaria and HIV/AIDs control under the Global Fund (Raykar, 2018; Jamison, Jha, Laxminarayan and Ord, 2013; Global Fund, 2019) and not used to inform country level policy. The use of cost-benefit analysis is important if one wishes to compare interventions in malaria to non-health areas such as education, infrastructure and the environment.

The epidemiological modelling indicates that scaling up mass distribution of LLINs and improved testing have very large absolute impacts on burden and deaths avoided. Increasing coverage of LLINs from 56 per cent to 90 per cent will avoid 12.9m cases of uncomplicated malaria, 696,000 cases of severe malaria and 40,390 deaths between 2018 and 2030. Ensuring

[2] Most economic analyses of malaria interventions have been cost-effectiveness analyses (CEAs) though these have typically been through the lens of maximizing the health return on health system resources, as is common with CEAs – and are silent on overall social welfare impacts.

testing of (nearly all of) the last 10 per cent of suspected cases of malaria that present at health facilities will avoid 17,340 cases of uncomplicated malaria, 434,780 cases of severe malaria and 24,770 deaths over the same time period. Scaling up coverage of SMC in children in the Guinea Savannah zone from 23 per cent to 90 per cent is expected to avoid 964,170 cases of uncomplicated malaria, 72,450 cases of severe malaria and 3,265 deaths.

Assessed against the costs of the interventions derived from Ghana specific studies, our cost-benefit analyses suggest increasing coverage of testing of suspected malaria cases in health facilities likely has the highest benefit-cost ratio (BCR) with a value of 134. Distribution of LLINs has the second highest BCR of 44 and SMC is lower than that with a BCR of 14. Despite the perceived superiority of testing and treatment, there is significant uncertainty over the feasibility and cost profile of this intervention, since it envisages reaching almost al the last 10 per cent of the population and there is no evidence for how costs scale at this coverage rate. Our finding of a BCR around 134 conjectures a 10x cost premium to reach the last 10 per cent, relative to the average cost for the first 90 per cent of suspected malaria cases, but this is speculative. In contrast, the strength of evidence for bed net distribution, on both the cost and benefit side, is very strong. It is up to policy makers to trade-off between quality of evidence and size of BCR in deciding how to employ marginal funds.

Several policy implications arise from our analysis. First is that the NMCP should strongly consider scaling up distribution of bed nets to 90 per cent of households, up from current levels of 56 per cent. This has a very high BCR of 44, and has the largest absolute impact of the three interventions analyzed in this paper. The strength of evidence for this finding is very strong. Second, due to the high BCR, the NMCP should consider further efforts to ensure suspected malaria cases are properly tested using RDT or microscopy. This would involve improved training, minimizing stock outs of key equipment and continuous monitoring and evaluation. It would also be pertinent to conduct initial small-scale investigations regarding the costs to see if they conform to our assumptions. Lastly, our findings suggest further scale up of SMC has the lowest BCR of the three strategies studied. That said, the reported central BCR of 14 for SMC is still very high relative to many other interventions within the *Ghana Priorities* series.

The rest of the paper is structured as follows. The next section describes the epidemiological model used to estimate impacts of the interventions. Section 3 describes the valuation approaches used for avoided morbidity and mortality. Sections 4 through 6 document the results of the cost-benefit analyses. Section 7 concludes.

2. Description of Epidemiological Model

2.1 Methods of Epidemiological Model

The epidemiological model used in this analysis is based on the Susceptible-Infected-Removed/Recovered-Susceptible (SIRS) framework. Using ordinary non-linear differential equations, modified compartmental malaria transmission models were developed and then fitted to malaria morbidity and mortality data for various transmission settings in Ghana. A more detailed description of the model can be obtained from the supplementary files from Awine (2019).

The three sub-populations within the different transmission settings of the country, namely the Guinea Savannah, Transitional Forest and the Coastal Savannah zones were considered for model simulations from 2018 to 2030. These correspond to a broad classification of the country into three ecological zones with similar meteorological characteristics (Awine et al. 2018; Kermack and Mckenderick, 1927; Mandal et al. 2011).

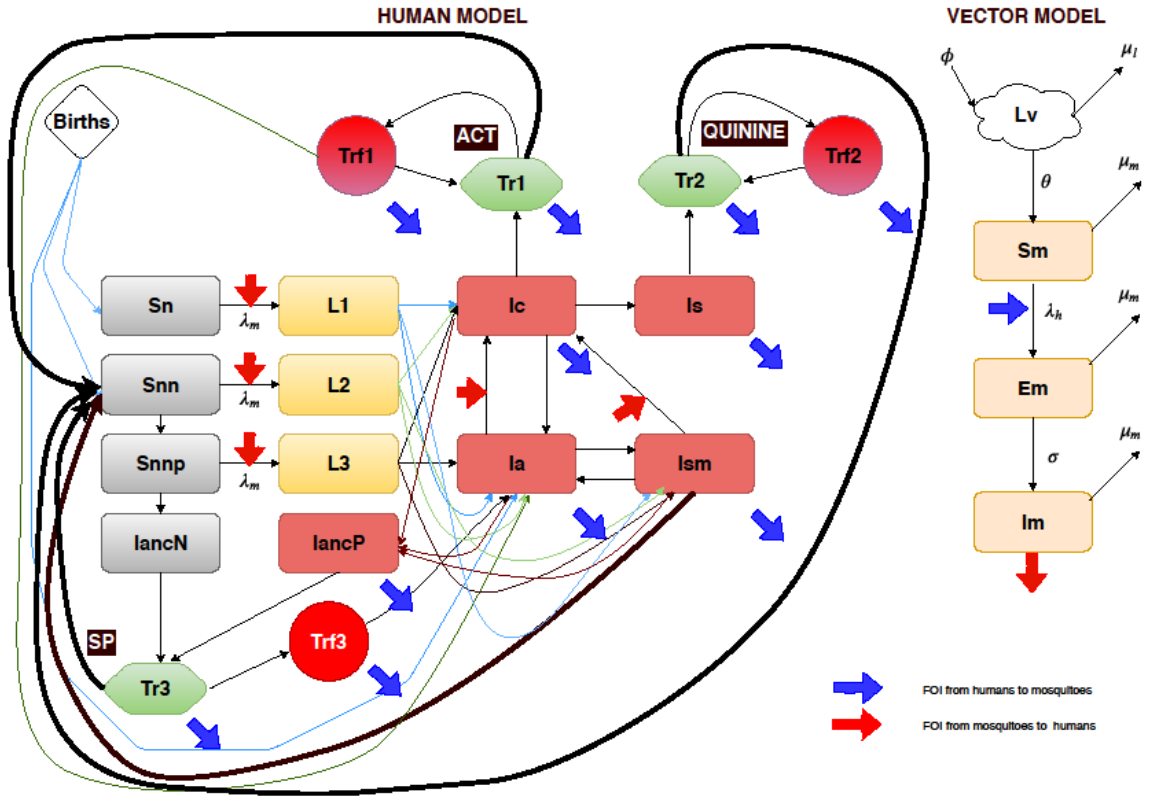
As shown in Fig 1, the base model is a closed population model and the structure includes compartments for human population coupled with a vector population model. Two forces of infection are involved, mosquito to human ($\boldsymbol{\lambda_{mh}}$) and human to mosquito transmission ($\boldsymbol{\lambda_{hm}}$). Compartments contributing to the both forces of infections are designated by the red and blue bold arrows respectively.

Epidemiological features of malaria transmission dynamics such as immunity and super-infection, typical of an endemic setting such as Ghana's, were accounted for given the high transmission potential across the country.

Dynamics of the vector population are governed by zonal temperatures and rainfall. The survival potential of young immature mosquitoes (larva and pupa) are dependent on the average monthly temperature and the suitability of the environmental carrying capacity, determined by rainfall. Additionally, parasite development rate, maturation and survivability of adult mosquitoes depend on environmental average monthly temperature (Tran et al. 2013; Agusto et al. 2015).

The transmissibility of the malaria parasite after drawing of a blood meal from humans, through bites by the mosquito, are governed by biting rates (BR) from field studies in the respective zones.

Figure 1: Malaria model structure



Sn, **Snn** and **Snnp** represent the susceptible human compartments respectively for younger children under 6 years of age, adults and pregnant women. **L1**, **L2** and **L3** are stages of latent infection. **Ic**, **Ia**, **Is** and **Ism** represent symptomatic infection, asymptomatic infection, severe infection and sub-microscopic infection respectively. Pregnant women at antenatal clinic (ANC) without infection, **IANCN** or **IANCP** once infected. **Tr1**, **Tr2** and **Tr3** represent treatment compartments for confirmed uncomplicated malaria (**Ic**), severe malaria (**Is**) and routine monthly SP prophylaxis for pregnant women at ANC, Possible treatment failure is captured by **Trf1**, **Trf2** and **Trf3** respectively for the three treatment options. **Vector population: Lv** represents larva population and **Sm** susceptible mosquitoes. Exposed mosquitoes are captured in **Em** compartment. Whereas infectious mosquitoes are in the **Im** compartment.

2.2 Model calibration

Data from 2008 to 2017 obtained from the District Health Information Management System (DHIMS) platform was used for model calibration using the Approximate Bayesian Computation methods. This data includes routine health facility confirmed malaria cases and deaths in all districts across Ghana. All predictions were adjusted for population growth using projected mid-year population estimates from the DHIMS.

3. Common parameters used in cost-benefit analysis

3.1 General parameters and baseline

Each of the analyses covers a time period from 2018 to 2030. Following *Ghana Priorities* standardized assumptions, we adopt discount rates of 5 per cent, 8 per cent and 14 per cent for the cost-benefit analyses (Wong and Dubosse, 2019). All figures noted in this study are denominated in 2018 GH¢ unless otherwise specified. Table 1 outlines the baseline variables for the three interventions and other malaria outcomes. The burden of malaria herein refers to the total incident cases attributable to malaria.

Table 1: Baseline parameters

Variable	Value in 2018	Source
Burden of malaria (uncomplicated)	6,218,000	Epidemiological model
Burden of malaria (severe)	345,000	Epidemiological model
Cases of malaria treated in health facilities (uncomplicated)	4,661,000	Epidemiological model
Cases of malaria treated in health facilities (severe)	332,000	Epidemiological model
Deaths from malaria	18,960	Epidemiological model
Household coverage of bed nets	56%	NMCP programmatic data
Children treated with SMC in Guinea Savannah zone	100,000	NMCP programmatic data
Testing of suspected malaria patients via RDT or microscopy in health facilities (as a % of all suspected patients)	90%	NMCP programmatic data

3.2. Valuing morbidity avoided

The model provides output that allows us to calculate three different types of malaria morbidity outcomes: i) individuals who contract uncomplicated malaria and do not seek treatment at a health facility ii) individuals who contract uncomplicated malaria and seek treatment at a health facility iii) individuals who contract or progress to severe malaria all of which are assumed to be treated at a health facility. Following *Ghana Priorities* standardized assumptions, these are valued using a cost-of-illness approach incorporating the full societal costs including health system, direct and indirect household costs. The benefit of an avoided case is simply the cost-of-illness avoided.

There have been numerous studies in the Ghanaian context that provide evidence on the societal costs of uncomplicated malaria (Tawiah et al. 2016a; Tawiah et al 2016b; Dalaba et al. 2016; Escribano-Ferrer et al. 2017; Sicuri et al. 2014; Ansah et al 2013). A summary of these six

papers is reported in Table 2 with conversion to 2018 GH¢ values using World Bank Database GDP deflators. While each paper reports societal costs, the unit of inquiry varies with four of the papers indicating costs for treatment at health facilities (Tawiah et al. 2016b; Escribano-Ferrer et al. 2016; Sicuri et al. 2014; Ansah et al. 2013) and the other two reporting costs averaged across treatment seeking and non-treatment seeking individuals (Tawiah et al, 2016a; Dalaba et al, 2016). Half the papers report costs for children, and the other half report costs averaged across children and adults.

The reported figures vary from a low of GH¢ 36.7 to a high of GH¢ 102.4. However, outside of these two extremes the reported values for the remaining four studies are quite consistent spanning a range of only GH¢ 10 (GH¢ 71.2 to GH¢ 81.6). It is important to note that the reported figures account for productivity loss from adults or in the case of children, their caregivers.

Table 2: Summary of societal costs per case of malaria or fever

Study	**Sample characteristics**	**Reported societal cost**	**Cost in 2018 GH¢**
Tawiah et al. (2016a)	1,222 individuals (adults and children) who sought treatment for fever in Kintampo area	2011 GH¢ 22.2 per episode of fever	GH¢ 76.2 per episode of fever
Tawiah et al. (2016b)	3,046 children living who sought treatment for fever at health facilities in Kintampo area (part of RCT)	2009 GH¢ 15.6[a] per episode of child fever treated at health facility	GH¢ 71.2 per episode of child fever treated at health facility
Escribano-Ferrer et al. (2017)	Children from 648 households who had malaria in the Volta and Northern regions and were treated at health facilities	2014 USD 7.98[b] per episode of child malaria treated at health facilities	GH¢ 36.7 per episode of child malaria treated at health facilities
Dalaba et al. (2014)	1,324 individuals (adults and children) who sought treatment for fever in Kassena-Nankana districts	2010 GH¢ 20.9[c] per episode of fever	GH¢ 81.6 per episode of fever
Sicuri et al. (2014)	Modelled estimates of costs of treating uncomplicated malaria in children with **no cost assumed for treatment outside health facility**	2010 USD 7.99 per case of uncomplicated malaria in children	GH¢ 73.1[d] per treatment at health facility in children, conditional on seeking treatment
Ansah et al. (2013)	7,236 individuals (adults and children) with suspected malaria who visited a health facility in Dangme West (part of RCT)	2009 GH¢ 22.5[e] per suspected case of malaria treated at health facilities	GH¢ 102.4 per suspected case of malaria treated at health facilities

(a) simple average of societal costs across treatment and control arms (see Table 2 of Tawiah et al. 2016b) (b) simple average of societal costs from CBA and CHPS facilities across both regions (c) currency year not reported – assumed to be 2010 as per time of survey; (d) Because the results of Sicuri et al. (2014) do not include any costs associated with treatment outside the health facility, we divide the reported value by the presumed health treatment-seeking rate in their model (0.7) to provide a more meaningful figure of cost per treatment at health facility, conditional on seeking treatment; (e) Simple average of societal costs across the treatment and control arms (see Table 2 of Ansah et al. 2013).

The parameters for morbidity benefits in our cost-benefit model are drawn from Tawiah et al. (2016a), since that is the only study that reports societal costs split between different types of health seeking modes, allowing us to estimate costs across those who did and did not seek treatment at health facilities.

We take the weighted average societal costs reported in that paper from those who visited CHPS facilities, clinics, health centers or outpatient clinics at hospitals as the cost associated with treatment at a health facility. This equals 2011 GH¢ 25. For the cost associated with no treatment at a health facility we estimate the weighted average societal costs from those who visited a chemical seller, a drug peddler, herbalist, pharmacy or did not seek treatment whatsoever. This equals 2011 GH¢ 18.

We make two adjustments to these figures. The first adjustment is for inflation using the World Bank GDP deflators. The second adjustment is to account for the effects of insurance. In Ghana, some proportion of individuals has their costs subsidized under the National Health Insurance Scheme (NHIS). However, the co-payment amount by the government represents a cost to society and should be included in the calculation. The reported values in Tawiah et al. (2016a) do not account for insurance effects (though the paper notes 48 per cent of the individuals sampled had insurance), so we draw upon the findings of Dalaba et al. (2014) who report that the costs of fever for the uninsured are 10 per cent higher than the costs of the insured. We apply this adjustment only to the cost of those that seek treatment in health facilities, since seeking treatment outside of health facilities is not covered under NHIS. After these two adjustments, the costs of uncomplicated malaria for those who seek treatment at health facilities equals 2018 GH¢ 91. For those who do not seek treatment at health facilities this equals 2018 GH¢ 61.

For the costs of severe malaria, we identified only one study from Ghana (Sicuri et al. 2014). That paper models the societal costs of hospitalization, cerebral malaria and sequelae for children. We estimate the weighted average costs of these three events and convert to 2018 figures, for a cost of severe malaria equal to 2018 GH¢ 496.

3.3 Valuing mortality avoided

Mortality avoided follows *Ghana Priorities* standardized assumptions and is based on guidance provided by Robinson et al. (2019). Each life year lost is valued at 1.2x GDP per capita in the

initial year rising to 1.6x GDP per capita in 2030. For child deaths avoided we assume years of life lost avoided of 65.2 and for adults 36.1 as per Ghanaian life tables (WHO, 2019).

4. Distribute and sustain 90 per cent coverage of LLIN

4.1 Description of intervention

This intervention envisages a scale up of LLIN coverage from baseline levels of 56 per cent to 90 per cent via mass distribution. Coverage is defined as a household owning one LLIN for every two household members. This is consistent with the WHO (2007) indicator of coverage- the percentage of people who have access to LLIN in the household, assuming that 1 net covers two persons. We assume it takes three years, from 2019 to 2021 to reach 90 per cent coverage and from 2022 onwards, this coverage level is sustained. The intervention involves a continuous distribution of bednets; requiring approximately 2 million more bed nets to be distributed every year in the first three years. Thereafter, the number of bed nets distributed annually equals 2m to replace LLINs distributed three years prior plus a small factor to account for population growth.

Besides coverage, another key parameter is LLIN usage (defined as the per cent of LLIN owned that are actually used). Baseline LLIN usage levels by zone (Guinea Savannah, Transitional Forest and Coastal Savannah) were sourced from Koenker et al. (2018) and population weighted estimates indicate baseline usage of LLIN across Ghana of 44.2 per cent for the entire population. The analysis assumes that mass distribution does not change average LLIN usage.

4.2. Epidemiological impact of intervention

Scale-up

Scale-up of LLINs from a baseline universal coverage of 55.6 per cent to 90 per cent while maintaining the usage of LLINs at 44.2 per cent (baseline), across all zones leads to a series of improved malaria outcomes: the benefits are small at first, but then increase rapidly as the intervention intensifies. Over the time horizon, there is a 13.7 per cent decrease in the burden of malaria, equivalent to 989,000 incident cases avoided per year on average (Figure 2). This also translates to an equivalent percentage reduction in treatments required at health facilities for malaria equal to 736,000 treated cases avoided per year on average. Increased LLIN coverage would result in 3,107 avoided deaths per year on average (Figure 3).

Figure 2: Burden of malaria, LLIN intervention vs baseline

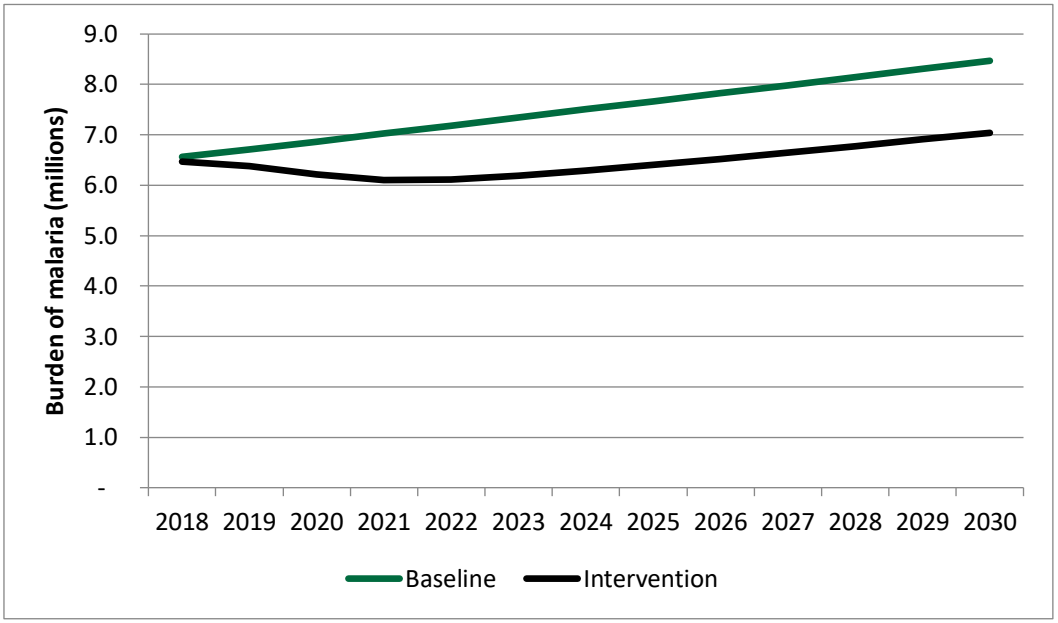
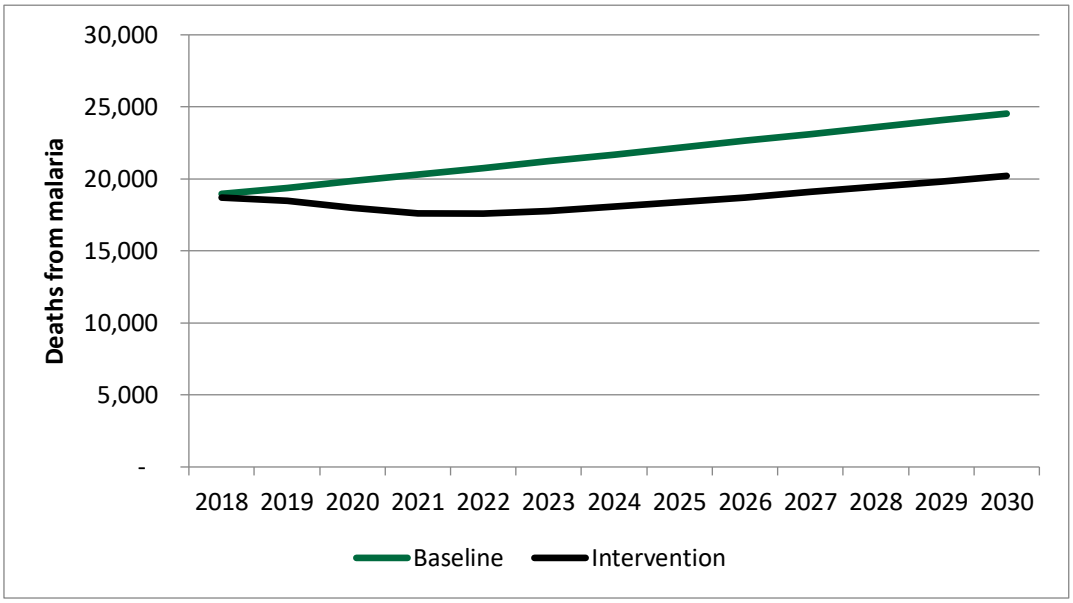


Figure 3: Deaths from malaria, LLIN intervention vs baseline



4.3 Calculation of Costs of Benefits

4.3.1 Estimation of Costs

This section relies largely on the economic cost estimates of bed nets distribution provided by Paintain et al. (2014). That study estimated the costs of mass bed net distribution for three regions namely; Central, Western and Brong Ahafo. Though the selection of the regions was not random, it is a fair representation given Ghana's ecological zones and regional differences

in malaria prevalence.[3] Central and Western regions are in the coastal and forest ecological zones; and Brong Ahafo region includes part of forest and savannah ecological zones. A total of 3,664,028 LLINs were delivered; representing 99 per cent of procured LLIN for the three regions. The evaluation was preceded by a pre-campaign baseline data survey on LLIN ownership and use (September – December, 2011); followed by the distribution of the LLINs between November and December 2011 in the Central and Western regions while that of Brong Ahafo was carried out between May and June 2012. These were followed by post campaign household survey conducted between September-October 2012 (Central and Western regions); and October-November 2013 (Brong Ahafo region). They report an annual average annualized economic cost of 2012 USD 2.59 per net distributed, including USD 1.90 for the net itself. These annualized figures assume three-year bed net life span and a 3 per cent discount rate. We convert this to a unit cost figure in the year incurred which equals USD 7.33 per bed net distributed, USD 5.37 being the cost of the bed net itself. To estimate the cost of LLIN distribution for this cost-benefit analysis in 2018 GH¢, we first convert the non-bed net proportion of costs (USD 1.95) at the 2012 USD- GH¢ exchange rate and then inflate using GDP deflators. This equals GH¢10.4.

The costs of LLINs have declined over time in real and nominal terms with current procurement costs less than 2 USD for most LLINs (UNICEF, 2018). Here, we adopt a price of USD 3 which accounts for both procurement and delivery to Ghana and equals GH¢ 13.7. The total cost per bed net distributed is therefore GH¢24.1.

The bed nets distribution intervention targets 90 per cent of all households in Ghana. The amount of extra bed nets distributed under this intervention is 1.9 million in 2018 increasing to 2.5 million in 2030. We further assume that the real cost of procuring and delivering the bed net to Ghana is constant over the period of analysis, while the real cost of distribution within the country increases with the real GDP per capita growth. The total cost of intervention for 2018 is estimated to be GH¢ 45 million and this is projected to increase to GH¢ 73 million in 2030. The total cost of the intervention is estimated at GH¢ 442 million at an 8% discount rate.

[3] i.e. Central and Western regions are in the coastal and forest ecological zones; and Brong Ahafo region includes part of forest and savannah ecological zones. A total of 3,664,028 LLINs were delivered; representing 99% of procured LLIN for the three regions.

4.3.2 Estimation of Benefits

Applying the valuation approaches from Section 3 and the reported epidemiological impacts from Section 4.2 we estimate morbidity avoided benefits of GH¢ 9 million, mortality avoided benefits of GH¢ 139 million in 2018. These are expected to increase to GH¢ 230 and GH¢ 4,803 million respectively in 2030. Over the time horizon we estimate total benefits to equal GH¢ 19,359 million at an 8% discount rate. Avoided mortality comprises approximately 96% of the total benefits.

4.3.3 Summary of costs and benefits

Table 3: Summary of Costs and Benefits from LLINs

Intervention	Discount Rate	Benefit (GH¢ millions)	Cost (GH¢ millions)	BCR
Distribute and sustain 90 per cent coverage of LLIN	5%	24,450	533	46
	8%	19,359	442	44
	14%	12,653	318	40

Table 3 summarizes the costs and benefits of the intervention. The analysis indicates large benefit-cost ratios under all discount rate scenarios, with a central estimate of 44.

4.4 Discussion

The results from Table 3 provide strong support for the scale up of LLIN coverage to 90 per cent. If implemented, it would avoid around 1 million cases of malaria every year and 3,107 associated deaths. The strength of the evidence for LLIN distribution is assessed as very strong. There have been several meta-analyses confirming the protective effectiveness of bed nets across malaria endemic regions (Lengeler, 2004; Kesteman, Randrianarivelojosia and Rogier, 2017; Pryce, Richardson and Lengeler, 2018) and a broader modeling study indicating that LLIN should be the first intervention scaled up in malaria endemic regions (Winskill et al. 2019). The cost figures are taken from actual procurement data by UNICEF and large-scale distribution of bed nets in Ghana, both of which should be representative of future distribution programs.

The effectiveness of a distribution campaign would increase if household usage of LLIN, conditional on ownership, were higher. As stated, current estimates of usage of LLIN is 44.2 per cent so there is much room for improvement on this metric in Ghana. Paintain et al. (2014) highlight a potential approach – so called ‘hang-up’ campaigns, where bed net distributors enter

people's houses to hang up the nets for them. Paintain et al. assess that this would only cost 10 per cent more per bed net distributed – in time spent by distributors and the household - but result in an increase in the odds of LLIN usage by 57 per cent. This implies an increase in usage to 55 per cent, from 44.2 per cent.

However, there appear to be practical challenges in the implementation of hang-up campaigns in Ghana. At the roundtable validation workshop preceding the finalization of this report, experts from the Ghana Health Service and the National Malaria Control Programme (NMCP) *inter alia* shared experiences regarding the difficulty of implementing hang up campaigns including the need to procure related materials such as nails and tools, volunteers dropping out of the campaign for lack of financial incentives and recipients denying volunteers access to their homes. It is possible that Paintain et al. document an atypical effect from hang-up in Ghana. As such, we do not officially conduct a cost-benefit analysis from hang-up campaigns in this report. Instead we only note that if it were possible to increase usage of LLINs at relatively low cost, then the BCR of this type of intervention could be even higher.

5. Seasonal Malaria Chemoprevention to 90 per cent of children in the Guinea Savannah zone

5.1 Description of intervention

This intervention envisages an increase in the coverage of SMC among children 3-59 months old in the Guinea savannah zone. The treatment regime comprises SP +AQ for four rounds (four months) through the rainy season (July to Oct). Close to 22 per cent of children aged 3-59 months were treated for four rounds in 2017. This intervention aims to increase the population coverage to 90 per cent. At baseline the number of children treated for SMC is estimated at 120,000. Increasing to 90 per cent represents an additional 400,000 more children being treated in the first year, which increases over time to account for population growth. On average, over the time period of analysis, the intervention treats 434,000 more children with SMC per year.

5.2. Epidemiological impact of intervention

The intervention reduces the malaria burden throughout the population by 6 per cent on average or around 74,000 cases per year (Figure 4). This small figure is partially due to the fact that the

intervention is only focused on a subset of the population, namely children aged 6-59 months. The intervention reduces the annual number of deaths associated with malaria by 251 on average (Figure 5). All of these are assumed to be children.

Figure 4: Burden of Malaria, SMC invertervention vs baseline (Guinea Savannah region only)

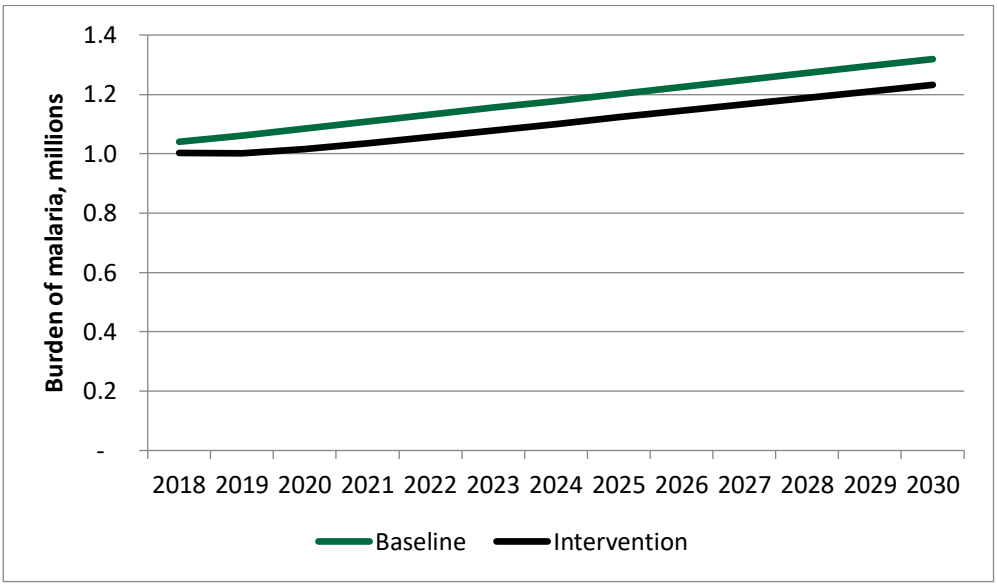
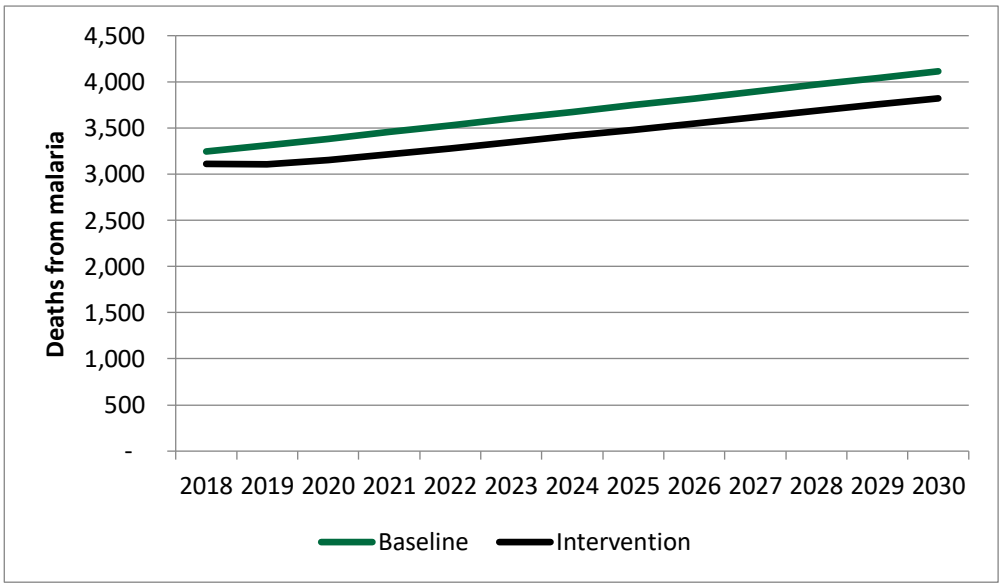


Figure 5: Deaths from Malaria, SMC invertervention vs baseline (Guinea Savannah region only)



5.3 Calculation of Costs and Benefits

5.3.1 Estimation of Costs

The costs of this intervention are drawn from Novignon et al. (2016b) which estimated the impact of the SMC strategy on malaria morbidity and mortality in children below age five using cluster-randomised comparative design with one intervention district (Lawra) and a control district (West Mamprusi).[4]

Nonvignon et al. (2016b) reported a financial cost of GH¢ 51 (US$9.66) per fully dosed child. This figure includes all monetary expenses such as medicines, staff costs and volunteer incentive payments. However, this reported value incorporates costs for children who received fewer than the full dose (in other words, the numerator includes costs of children who received four rounds of SMC *or less*, while the denominator only includes children who received all four rounds only). Given that our benefits are modeled for those that receive the full four rounds of SMC, the more appropriate matched cost is that associated with receiving four full rounds only. Unreported figures in Nonvignon et al. (2016b) indicate that this cost is 23% less than the reported cost per fully dosed child. This translates to a financial cost of 2018 GH¢ 40 per child receiving the full course of SMC, after making the necessary exchange and inflation adjustments.[5]

To this value, we add unaccounted costs associated with caregiver time. The NMCP estimates that each caregiver is required to spend 20 min per round, or a total of 80 min over the course of four months (private communication with Dr. Adomako, SMC coordinator). Using standard rural wage rate of around GH¢ 5 per hour and applying a 50% reduction for non-productive time as per *Ghana Priorities* assumptions, yields a cost of caregiver time equivalent to GH¢ 3. Therefore the total cost of providing a full course of SMC over four months is estimated at GH¢ 43.[6]

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[4] Lawra is located in the Upper West region while West Mamprusi is in the Northern region. Though in different regions, both districts are very similar in terms of malaria transmission and other socio-economic attributes.

[5] We are very grateful to Justice Nonvignon for assisting with interpretation of the results in Nonvignon et al. 2016b.

[6] Nonvignon et al. (2016b) provide an estimate of the economic cost of delivering SMC, though this is substantially higher than our estimated economic costs of GH¢ 43. Discussions with NMCP representatives indicate that the way SMC is delivered now differs substantially from how it was delivered in the pilot setting analyzed by Nonvignon et al. 2016b, with less volunteer and caregiver time required in the current program set up. We have therefore made a new estimate by adding the financial costs in Nonvignon et al. to newly estimated economic costs.

This unit cost value is assumed to increase over time in real terms with real GDP per capita growth, except for the component associated with the drugs (25% of the cost as per Nonvignon et al., 2016b). Drug costs are assumed to stay constant in real terms.

The total cost of increased SMC is estimated at GH¢ 17 million in the first year, rising to GH¢ 29 million by 2030. The total estimated cost is GH¢ 167 million over the time period at an 8 per cent discount rate.

5.3.2 Estimation of Benefits

Applying the valuation approaches from Section 3 and the reported epidemiological impacts from Section 5.2 we estimate total health benefits of GH¢ 2,303 million over the time period at an 8 per cent discount rate. Approximately 4 per cent of these benefits are from morbidity avoided, with the remaining benefits attributable to mortality avoided.

5.3.3 Summary of costs and benefits

The costs and benefits of SMC prevention are summarized in Table 4. SMC has a central BCR of 14.

Table 4: Summary of Costs and Benefits from SMC

Discount Rate	Costs (2018 GH¢, millions)	Benefits (2018 GH¢, millions)	BCR
5%	2,839	202	14
8%	2,303	167	14
14%	1,586	120	13

5.4 Discussion

The results indicate that expanding SMC in the Northern Region of Ghana has a relatively large BCR of 14. This finding conforms to recommendations from other studies that support SMC as a highly cost-effective intervention (e.g. Pitt et al. 2017; Winskill et al. 2019). This finding is based on an estimated economic cost of delivering a full course of SMC at GH¢ 43 or around USD 9.40. While the result suggests large value for money with BCR of 14 (reflecting a return on investment ~4-5 times the median intervention in the *Ghana Priorities* series), this is the lowest of the three strategies investigated in this paper. DHIMS data indicate that malaria incidence during the four months of the high transmission season is 'only' 60% of yearly malaria incidence. While this is 3x the transmission rate of the non-SMC season, the strategy cannot provide protection for the periods associated with 40% of the annual malaria incidence.

During the course of the investigation that led to the results of this paper we surveyed the literature on the costs of providing SMC or its predecessor, intermittent preventative treatment in children (IPTc) in sub-Saharan Africa. We identified six papers across eight countries (see Table 5). A major theme that arose from this analysis is the lack of studies that have estimated the economic costs of providing SMC from a whole of society view. Four studies limited their analyses to either financial costs or provider costs. Social cost-benefit analyses, such as the one conducted in this paper, would generate more precise BCRs if they could drawn from carefully conducted studies of economic costs from a whole of society view. Only two of the studies surveyed, Nonvignon et al. (2016b) and Conteh et al. (2010) report costs from this lens. Unfortunately, they report highly divergent cost estimates.[7] There is a clear need for further research in this area.

Table 5: Overview of studies examining the costs of delivering SMC or IPTc

Study	**Study setting**	**Reported financial cost for all courses**	**Reported economic cost for all courses**
Nonvingon et al. (2016b)	Provision of SMC to around 150,000 children aged 3-59 months in 11 districts in Ghana 4 courses	2015 USD 9.66 provider perspective	2015 USD 67.35 societal perspective 2015 USD 22.53 provider perspective
Pitt et al., (2017)	Door-to-door SMC delivery to 180,000 Senegalese children (3 months up to 10 years old) 3 courses	2010 USD 1.22 provider perspective	2010 USD 1.51 provider perspective
Gilmartin and Collins (2016)	Cost analyses from programmatic data from six countries supported by UNITAID-funded ACCESS-SMC project in 2015 4 courses	Burkina Faso: $4.31 Guinea: $5.02 Mali: $4.03 Niger: $3.45 Nigeria: $4.49 The Gambia: $6.07 (All 2015 USD provider perspective)	Not estimated
Conteh et al (2010)	Provision of different drug combinations (IPTc) to around 1800 children (3-59 months) in Ghana	Not reported however average cost per child participating is 2008 USD 10.46 (AQ+AS monthly)	2008 USD 14.79 societal perspective (for receiving at least the first dose of AQ+AS monthly only)
Patouillard et al. (2011)	Provision of IPTc to around 1000 children via different delivery modes in Ghana 4 courses	Not reported however average cost per child participating is 2008 USD 2.22 or 2.50 depending on delivery mode	2008 USD $7.56 or $8.51, depending on delivery mode, provider perspective
Bojang et al., 2011	Delivering IPTc using trekking teams to village health workers (VHW) to Gambian children 6 years or younger 3 courses	2008 USD 2.97 (using trekking teams) or 1.23 (using VHWs) per child receiving first dose of at least one treatment, provider perspective	2008 USD 3.47 (using trekking teams) or 1.63 (using VHWs3) per child receiving first dose of at least one treatment, provider perspective

[7] This could be partially attributable to the fact that Nonvignon et al (2016b) focus on SMC, while Conteh et al (2010) analyse IPTc.

6. Near Universal Testing and Treatment of Suspected cases

6.1 Description of intervention

For reliable diagnosis and appropriate use of antimalarials, the WHO recommends parasitological confirmation before treatment for all suspected malaria cases; hence attention given to the use of malaria rapid diagnostic tests (mRDTs). Though not practiced in all health facilities, Ghana is among the malaria endemic countries using these RDTs. Currently 90 per cent of suspected malaria patients who present at health facilities are tested. This intervention envisages a scale up to (nearly) 100 per cent of all suspected cases presenting at health facilities, requiring extra 36,150 patients to be tested per year on average.

6.2. Epidemiological impact of intervention

The impact of diagnostic testing on the burden of uncomplicated and severe malaria can be seen in Figure 6 and 7. It is apparent that testing and treatment has modest impact on the overall burden of uncomplicated malaria with an average of 69,850 cases avoided per year or around 1% of the baseline burden. This is unsurprising given that the intervention does not focus on vector control or prevention, but rather on diagnosis and earlier treatment. In contrast, reduction in the burden of severe malaria cases is significantly greater in percentage terms, with a 9% reduction equivalent to 33,450 cases avoided per year. Again, this is expected given the intervention's focus on improved diagnosis that lowers the risk of progression to severe malaria. The intervention averts 24,770 deaths between the period 2018 to 2030 (Figure 8).

Figure 6: Burden of uncomplicated malaria, testing intervention vs baseline

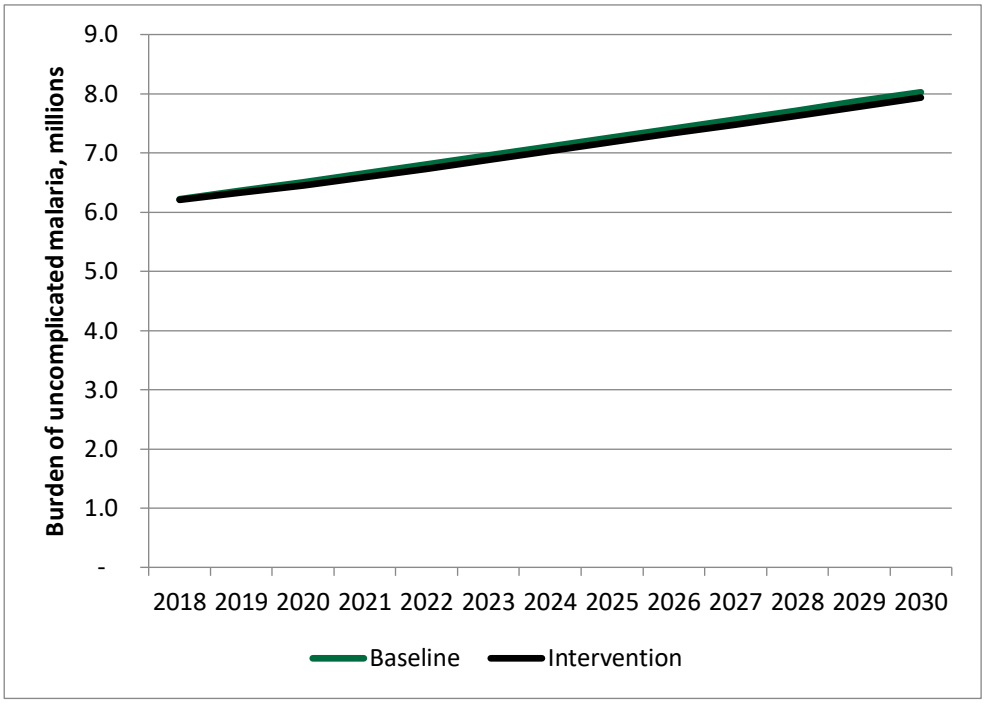


Figure 7: Burden of severe malaria, testing intervention vs baseline

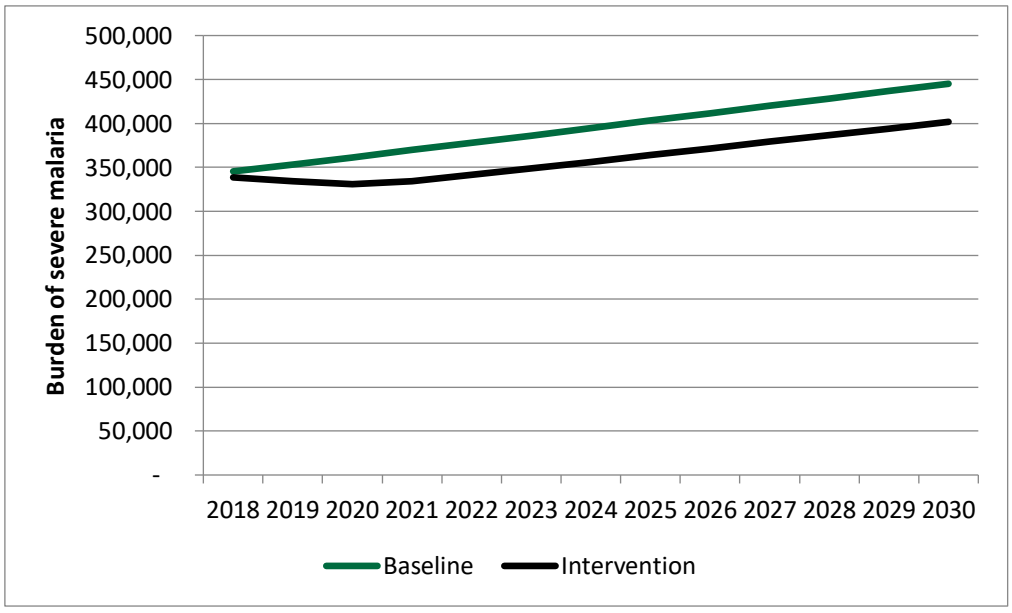
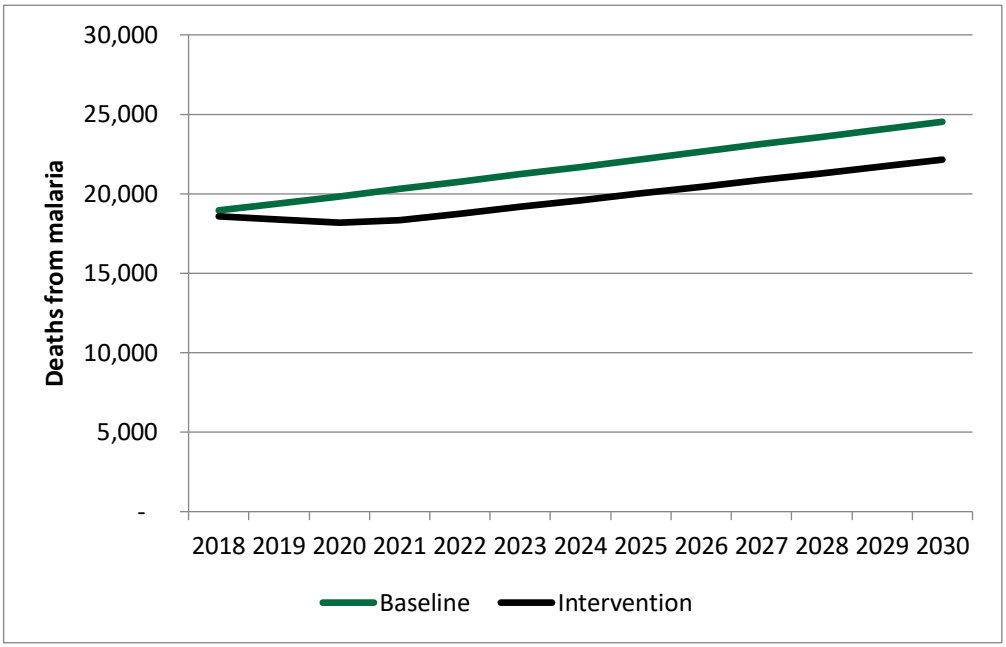


Figure 8: Deaths from malaria, testing intervention vs baseline



6.3 Calculation of Costs of Benefits

6.3.1 Estimation of Costs

The costs of testing and treatment of malaria presented in this section relies on estimates provided by Tawiah et al., (2016b). That study used a cluster randomized control design to assess the impact of introducing RDTs for malaria treatment among under-five children in a high transmission setting where presumptive diagnosis was the typical practice in public health facilities. The study presents the full societal economic costs of testing, training, supervision, drugs and household expenses between the RDT regime vs. the presumptive treatment regime. For the purposes of this study, the costs of training, testing and supervision of implementing RDT are considered the implementation costs of the intervention – i.e the figures that go into the denominator of the BCR. For drug costs and household expenses, we take the difference between these values under the RDT regime vs. the presumptive treatment regime and assess these as one of the benefits of the intervention, the idea being that improved diagnosis saves the health system and households from unnecessary costs. The training and supervision costs of the presumptive regime are ignored though one could argue this is also a saving to society. Under this approach, the average start up costs of implementing improved testing in a standard setting is GH¢ 25 per suspected malaria case presenting at health facilities. The benefits of avoided drug and household expenses is GH¢ 6 per suspected case tested.

An alternative cost categorization approach would be to apply a complete marginal analysis to all the cost categories i.e. take the difference between entire costs of RDT regime vs the presumptive regime. In this case the marginal cost of the intervention is only GH¢ 7.6 per suspected case presenting for malaria. This approach would serve to increase the reported BCRs by 3 times.

The costs reported by Tawiah et al. (2016b) represent an intervention conducted in a standard setting in Ghana when coverage of improved testing was nascent. However, the current study focuses on the remaining 10 per cent of cases presenting at health facilities that are not tested. It is unclear if the results in Tawiah et al. (2016b) are generalizable to the last 10 per cent of suspected patients. It is likely they would substantially different to the first 90 per cent. Some plausible reasons that these last 10 per cent are not tested include remoteness, lack of appropriately trained staff and poor monitoring. To reach the last 10 per cent would require intensified training, improved supply chain management to avoid stock outs and better monitoring.

We therefore conjecture a yet to be validated last-mile premium of 10x**,** suggesting that it will cost tenfold the average cost of GH¢ 24.9 to reach the remaining 10 per cent. This brings the cost per additional suspected case to approximately GH¢ 249. This assumption implies that the total cost of reaching the last 10 per cent costs a little more than reaching the first 90 per cent.

6.3.2 Estimation of Benefits

Applying the valuation approaches from Section 3 and the reported epidemiological impacts from Section 6.2 we estimate morbidity avoided benefits of GH¢ 4 and mortality avoided benefits of GH¢ 217 in 2018. These are projected to increase to GH¢ 42 and GH¢ 2,647 respectively in 2030. There are also modest savings in drug and household expenses, however these are less than 0.5% of total benefits. Total benefits are valued at GH¢ 11,595 million between 2018 and 2030 at an 8% discount rate.

6.3.3 Summary of costs and benefits

The costs and benefits of diagnostic testing are summarized in Table 6.

Table 6: Summary of Costs and Benefits from Diagnostic Testing

Discount Rate	Costs (2018 GH¢, millions)	Benefits (2018 GH¢, millions)	BCR
5%	14,448	104	139
8%	11,595	87	134
14%	7,799	63	124

Table 6 shows that the BCR of this intervention is very large with a central estimate of 134.

6.4 Discussion

The figures in Table 6 clearly indicate that among the interventions examined in this study, increasing testing and treatment of suspected malaria cases who present at health facilities to near universal levels has a very high BCR. However, this is based on an unverified (though perhaps plausible) average unit cost of GH¢ 249 to test the last 10 per cent of suspected cases, for which post-test confirmed malaria cases are treated. Whether a case is confirmed or otherwise, the average costs of testing is incurred for all suspected malaria cases. However, this renders the health system more efficient by not administering malaria treatment for non-malaria conditions and improving the accuracy of diagnoses.

How plausible is the 10x premium for the last 10 per cent of cases? There is little evidence to go by in the case of testing for malaria, but some studies from other health domains indicate that this is perhaps in the right 'ball-park'. A geospatial modelling study estimated the costs of reaching the most remote 20% of HIV-infected patients for viral load monitoring in Zambia (Nichols et al. 2019). They estimate that reaching the last 10 per cent would be 2x more costly than reaching the first 80 per cent. A review study conducted by USAID to determine the costs of delivering vaccines to the last mile in developing countries, showed that reaching the last mile constituted 54% of total logistics costs (Rosen et al. 2012). Assuming the last mile means reaching the last 10 per cent of beneficiaries, this implies a 10.5x unit cost premium, similar to our assumption.

7. Conclusion

The preceding analysis demonstrates that the most cost-effective intervention is testing and treatment (BCR=134) followed by continuous bed net distribution (BCR=44) and Seasonal Malaria Chemoprevention (BCR=14).

Table 7: BCR Summary Table

Intervention	**Discount Rate**	**Benefit** (2018 GH¢, millions)	**Cost** (2018 GH¢, millions)	**BCR**	**Quality of Evidence**
Distribute and sustain 90 per cent coverage of LLIN	5%	24,450	533	46	Very Strong
	8%	19,359	442	44	
	14%	12,653	318	40	
Seasonal Malaria Chemoprevention to 90 per cent of children in the Guinea Savannah zone	5%	2,839	202	14	Medium
	8%	2,303	167	14	
	14%	1,586	120	13	
Near universal coverage of testing and treatment at health facilities	5%	14,448	104	139	Limited
	8%	11,595	87	134	
	14%	7,799	63	124	

There are several policy implications of our study. First, bed net distribution should strongly be considered for scale up given the high BCR, large absolute benefits and very robust strength of evidence.

Second, the large BCR of 'testing and treatment of suspected cases' suggests that NMCP should consider scaling up this intervention in health facilities, with initial small-scale investigations regarding the costs of scale up to see if they conform to our assumptions. Additionally, given that a much larger share of individuals never reaches the health system, it is worth considering expanding more systematic testing to pharmacies since it would likely have a lower marginal cost than further expansions in health facilities. Monitoring and collation of data on tested cases at pharmacies could be valuable to help enforce treatment protocols and also inform future scale up of the intervention.

Lastly, our findings suggest further scale up of SMC has the lowest BCR of the three interventions examined in this study, with a return equivalent to 14 cedi for every cedi spent. However, this is still very large relative to other studies in the *Ghana Priorities* series.

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GHANA PRIORITIES

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