Research Paper 84

Cost Effectiveness of Malaria control programmes in Uganda: The case study of Long Lasting Insecticide Treated Nets (LLINs) and Indoor Residual Spraying

By

Ibrahim Kasirye

and

Gemma Ahaibwe

Abstract

Malaria is still highly prevalent in Uganda. The Ministry of Health in Uganda estimates that in a given year, at least 12.3 million cases of malaria are reported across the country. The disease is most prevalent among children aged 5 years and below and among pregnant women. The government of Uganda has intervened with several malaria programmes ranging from early detection and treatment of the disease among children as well as the provision of intermittent treatment of malaria among pregnant women. Starting in 2000, the Government of Uganda intensified efforts to provide Insecticide Treated Nets (ITNs) and Long Lasting Insecticide Treated Net (LLIN) as a primary means of preventing malaria. Even with the expansion in malaria control programmes, malaria remained endemic and the government reintroduced Indoor Residual Spraying (IRS) in 2006. This paper sets out to assess the cost effectiveness malaria control programmes in Uganda by comparing LLINs and IRS. Based on demographic data from the 2009 Uganda Malaria Indicator Survey the results show that IRS is significantly more effective in preventing malaria among children aged 5 years and below—with an incremental cost per child covered of US$28 per year and gross cost of US$ 701 per death averted.

Keywords: Malaria incidence, Malaria control programs (LLIN and IRS)

1. Introduction

Malaria accounts for a large burden of disease in developing countries especially in sub-Saharan Africa (SSA) and understanding the most cost effective methods for malaria control is both an economic and a public health priority. According to the World Health Organization (WHO), an estimated 190-330 million episodes of malaria occur each year globally and SSA accounts for about 90 percent of the global burden of malaria (WHO 2011). Some of the groups most vulnerable to malaria infection are children aged 5 years and below as well as expecting mothers. The 2011 World Health Statistics report shows that malaria accounts for 18 percent of death among children aged less than 5 years in SSA—compared to the global average of 9 percent. As such, reversing the incidence of malaria and other major diseases is one of the Millennium Development Goals (MDGs) adopted by the United Nations in 2000. In order to meet the MDG targets, international funding for Malaria prevention and treatment has increased tremendously. Through programs such as the Global Fund for AIDS, Malaria and Tuberculosis and the Roll Back Malaria Global Action Plan, at least US$ 1.1 billion was earmarked by international agencies for malaria interventions in SSA in 2008—up from US$ 250 million in 2004 (United Nations 2009). Over time, countries in SSA have adopted a number of interventions in order to prevent the spread of malaria parasites—ranging from vector control to prevention of malaria during pregnancy.

Malaria is endemic in Uganda. At least 95 percent of the country is infested with mosquitoes that carry the pathogens that cause malaria and at any given time at least 50 percent of Ugandans who report illness indicate having suffered from Malaria (Ssewanyana *et al* 2004). The Ministry of Health (MoH) in Uganda estimates that in a given year, at least 12.3 million cases of malaria are registered across the country (MoH 2010). The disease is most prevalent among children aged 5 years and below and among pregnant women. Initially, the Government of Uganda (GoU)'s efforts to control malaria focused in particular on early detection and treatment of the disease among children as well as the provision of intermittent treatment of malaria among pregnant women. Indeed, the above two strategies were the main methods used to prevent the spread of the disease in the 1990s (MoH 1999). Starting in 2000, the GoU intensified efforts to provide Insecticide Treated Nets (ITNs) as primary means of preventing malaria during the implementation of Health Sector Strategic Plan (HSSP I, 2000-2005). Overtime, the proportion of Ugandan households with at least one net increased from 13 percent in 2000 to 59 percent by 2009 (Uganda Bureau of Statistics and IFC Macro, 2010). Furthermore, by 2009, at least 46 percent of households had at least one Long Lasting Insecticide Treated Net (LLIN).[1] With support from the Global Fund for HIV/AIDS, Malaria, and Tuberculosis (GFMAT) under Round 7, the GoU intends to achieve universal coverage of LLINs by the end of 2013. At the same time, partly because malaria remained endemic even with the expansion in malaria control programmes, the government reintroduced Indoor Residual Spraying (IRS) in 2006. However, household access to IRS remains fairly limited across Uganda due to inadequate funding.

[1] Long Lasting Insecticide Treated Nets (LLINs) provide insecticide protection for about 5 years and do not require re-treatment like the previous traditional Insecticide Treated Nets (ITNs).

The current study examines the cost effectiveness of malaria control programmes in Uganda. Following other studies in the health literature (see e.g. Kolaczinski et al, 2010; and Goodman et al, 2001), cost effectiveness analysis deals with establishing which alternative service that provides the greatest result or outcome at the least cost. For the current study, we are interested in the malaria prevention methods that results in the lowest incidence at a given cost.

There are important reasons for focusing on Uganda. In particular, despite spending substantial resources on different modes of malaria prevention, there is limited information of the cost effectiveness of various interventions in reducing the burden due to malaria in Uganda. Previous analysis e.g. Kolaczinski *et al*. (2010) have focused on examining the cost effectiveness of different modes of delivering LLINs—either through targeted public health campaigns or through routine antenatal care services. To the best of our knowledge there are no studies evaluating the cost effectiveness of different malaria control programmes. The present study attempts to fill the policy vacuum by analyzing the cost effectiveness of the current two predominant methods of malaria prevention in Uganda—the provision of LLINs and IRS. We assess the cost effectiveness in terms of the cost of reducing a given number of malaria cases or deaths—following the framework used in earlier studies such as Goodman *et al*. (2001) for Kwazulu Natal in South Africa. In particular, we examine the cost effectiveness of delivering either LLINs or IRS for control of malaria among children aged 5 years and below in two districts of Uganda. The focus on this particular demographic group is because this is where the incidence of malaria is highest. Also, most of Uganda's malaria control efforts have targeted this particular age group in addition to pregnant women. Finally, the justification for focusing on infants is also partly guided the availability of accurate data on malaria incidence. Most recent malaria surveys in developing countries (like the one used in this study) only conduct laboratory tests for malaria for children aged 5 years and below. Consequently, for this age group, we have representative information based on laboratory diagnosis of malaria rather self assessed symptoms of malaria or rapid diagnostic blood tests (RDT).[2]

The rest of the paper is organized as follows; the next section, describes the context as well as the policy frameworks that guide malaria control programmes in Uganda. Section three describes the data and methods used in the analysis. The results for cost effectiveness analysis are presented in section four while section five provides the conclusions and implications of the study.

2. Context and policy framework for malaria control in Uganda

Malaria is the leading cause of illness in Uganda especially among children aged 5 years and below and at least 98 percent of malaria parasites are *P.falciparum*. Table 1, abridged from the 2009/10 Uganda National Household Survey (UNHS), indicates that between 2005/06 and 2009/10 malaria/fever remained the leading symptom for individuals reporting being ill

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[2] Previous studies such as Wongsrichanalai *et al.* (2007) highlight the possibility of false positive RDT test results. Indeed, this is also evident in Uganda. The 2009 Uganda Malaria Indicator Survey (UMIS) showed that 52 percent of children aged 0-59 months tested positive for malaria using RDT whereas only 42 percent of the category of children tested positive for malaria based on microscopy laboratory tests (UBoS and IFC Macro 2010).

during the past one month. In the past 10 years, there has been an increasing trend in clinically diagnosed malaria cases as captured by the national Health Management Information System (HMIS)—rising from 5.4 million cases in 2000/1 to 13.4 million by 2009/10 (MoH 2010). Indeed, the disease accounts for 25-40 percent of outpatient's visits; 20 percent of in-patient admissions; and 9-14 percent of in-patient deaths in public and NGO health facilities. Worse still, malaria accounts for 20-23 percent of infant deaths. The 2011 World Health Statistics show that Uganda's malaria mortality rate of 103 per 100,000 is more than seven fold that of Kenya (12/100,000)—18 percent more than that of Tanzania and 9 percent more than that of SSA (WHO 2011). As such, the control of malaria remains a public health priority in Uganda.

Table 1: Prevalence of illnesses/major symptoms suffered during the last 30 days prior to the interview, %

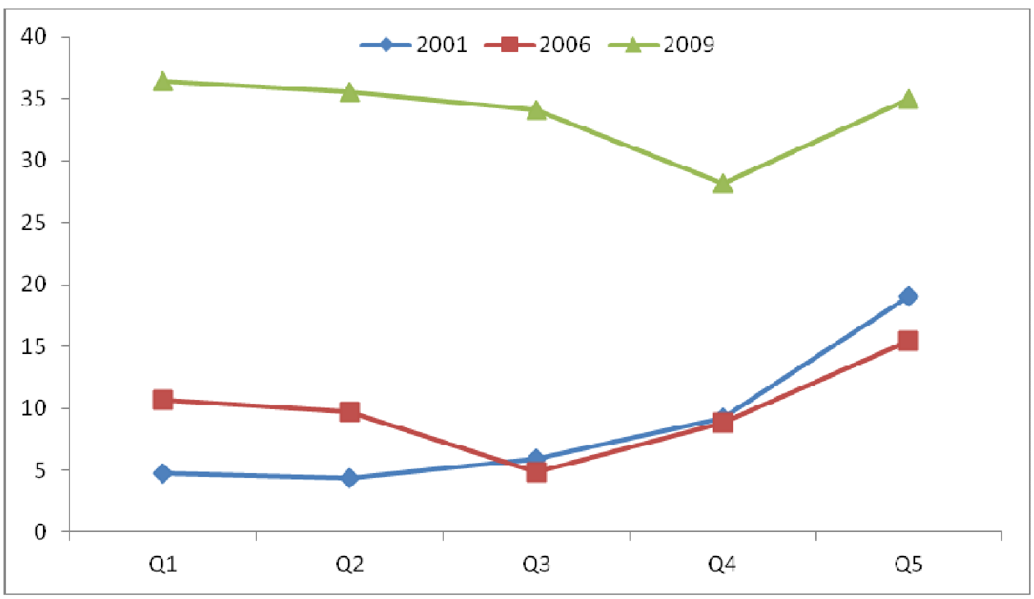
Type of illness	2005/06			2009/10		
	All Uganda	Urban	Rural	All Uganda	Urban	Rural
Malaria/fever	56.3	58.2	56.1	52.1	50.7	52.4
Respiratory Infections	14.3	14.6	14.2	14.8	17.3	14.5
Diarrhea	4.1	3.5	4.2	3.1	1	3.4
Urinary infections	0.3	0.1	0.3	0.2	0.1	0.2
Skin infections	3.2	3.1	3.2	1.6	1	1.7
Injury	2.7	2.5	2.7	2.7	2.7	2.7
Other	19.2	17.9	19.4	25.5	27.3	25.2
Total	*100*	*100*	*100*	*100*	*100*	*100*

Source: Uganda National Household Survey 2009/10 Socio-Economic Module Abridged Report (UBOS, 2010).

Given that malaria is endemic in Uganda, the country has implemented a number of control programmes. The main methods of malaria control have been through vector control—mainly through ITNs and more recently a switch to LLINs in addition to the Indoor Residual Spraying (IRS). Insecticide treated nets have been at the centre of Uganda's malaria control efforts in the past 15 years. In 1999, the GoU of Uganda proposed to increase the proportion of infants protected by ITN from 5 percent to 50 percent over a 5 year period (MoH 1999). Initially, nets were provided free to women attending antenatal clinics although the main targeted users were children aged 5 years and below. However, by 2006, only 21 percent of children aged 5 years and below were sleeping under a mosquito net although at least 34 percent of households in Uganda had access to at least one net (UBoS and ORC Macro International 2007). In 2008, the GoU in line with WHO recommendations modified the target groups for net provision—from focusing on infants only to attainment of universal coverage (defined as having at least one net per two people). In addition, a new type of mosquito nets were recommended by WHO—the Long Lasting Insecticide Treated Nets (LLINs). These kinds of nets are able to release insecticides for at least 5 years. As earlier mentioned, the most recent figures show that at least 46 percent of households in Uganda had at least one LLIN in 2009 and the use of LLINs among infants was 32 percent (UBoS and IFC Macro 2010).

Furthermore, over the past 10 years the usage of ITNs/LLINs has improved greatly regardless of welfare status. Figure 1 shows the trends in the usage of nets among children aged 5 years and below during 2001-2009 by welfare quintiles. It is indicated that usage across welfare groups has increased by about three fold during 2006 and 2009. The surge in usage of nets during this short time span is partly linked to support from the Global Fund to procure and distribute nets across Uganda. Specifically, during Round 4 and 7, Uganda received about US$190 million for malaria control efforts (PMI 2010).[3] Indeed, the US$125 million received under Round 7 of Global Fund was to be utilized to distribute 17.7 million LLINs during 2008-2013. Indeed, it is this external support that explains the relatively similar usage of nets by infant from both the poorest and richest households in Uganda observed in Figure 1. With expected funding from the Global Fund under Round 10, the MoH intends to conduct a second mass LLIN distribution campaign in 2014—to distribute 19.9 million LLINs. If the second mass campaign is implemented, the current Uganda National Malaria Control Strategic Plan (UNMCSP) 2010/11-2014/15 envisages increasing the proportion of households with at least one LLIN and that of infants sleeping under a LLIN to 85 percent by 2015 (MoH 2010a). In the intervening period during mass LLIN campaigns, the MoH plans to distribute at least 1.5 million nets annually—through antenatal clinics and during routine immunizations.

Figure 1: Trends in ITN/LLIN usage among infants by wealth quintiles, 2001-2009 (%)



Wealth quintiles

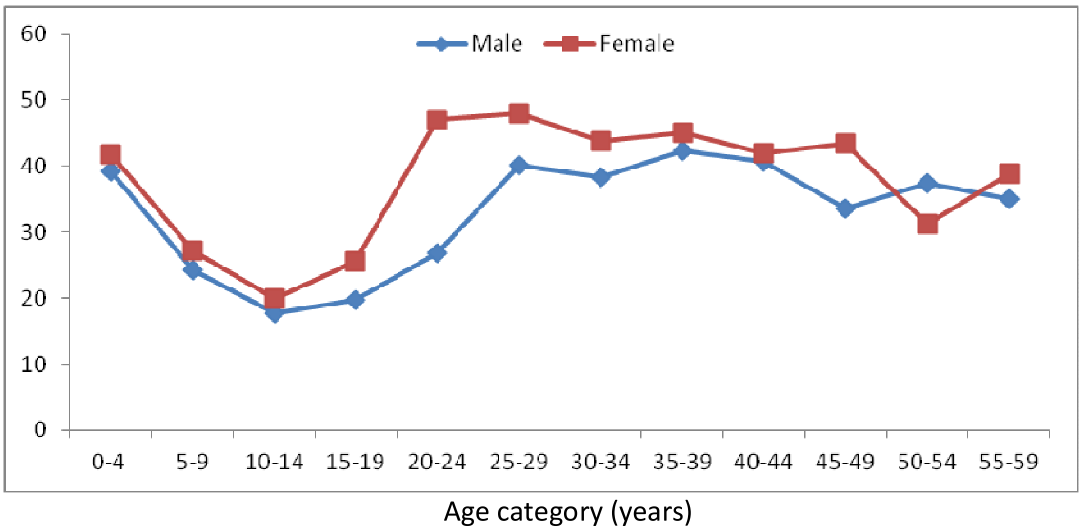
Sources: Uganda Demographic and Health Surveys 2000/1 and 2006 (UBoS and ORC Macro International: 2001, 2007); Uganda Malaria Indicator Survey 2009 (UBoS and IFC Macro, 2010).

On the other hand, the usage of LLINs is highest among infants and women in the reproductive age category. Figure 2 shows the trends in LLIN usage by five year age groups and gender and it is indicated that the usage of LLINs first declines after 4 years of age up to the age of 14 years and then rises up between 20-24 years up to about 48 percent and stabilises at 29 years. The same figure shows that there are minimal gender differences in

[3] Since 2002 Uganda has received about US$ 212 million from the Global Fund for malaria control efforts: US$ 23 million in Round 2; US$ 66 million in Round 4; and US$ 125 million during Round 7. For Round 10 (expected to be implemented during 2011-2012), it is expected that Uganda will receive US$ 53.9 million for malaria control.

the use of nets for individuals aged 0-14 years. After 14 years, females develop a slight advantage in usage of nets that rises up to 44 years before both sexes attain relatively similar rates of usages again. The gender gap in usage observed during 15-44 years may be partly explained by the fact that women in the reproductive age category are targeted to receive nets during the attendance of antenatal clinics.

Figure 2: Use of LLINs by gender and age groups in 2009 (%)



Source: Author's calculations from the 2009 Uganda Malaria Indicator Survey (UBoS and IFC Macro, 2010).

The other major method of vector control of malaria in Uganda is by way of indoor residual spraying. IRS was re-introduced in Uganda in 2006 after the pilot program undertaken during 1953-1963 in South Western Uganda that nearly eliminated malaria parasites in that part of Uganda (Zulueta *et al* 1964). From a pilot in one district in 2006 (*Kabale*), it was extended to 5 malaria endemic districts during 2008-2009 (*Amuru, Gulu, Kitgum, Apac*, and *Oyam*). In the above districts, at least 800,000 households with a population of 3 million persons were covered by IRS. Overtime, due to parasite resistance of insecticides, it has necessitated the two annual sprays in the targeted homes in order to maintain the level of protection. However, the roll out of IRS has been relatively slow (compared to LLINs) with only 6 percent of households in Uganda reporting at least one spray during the past 12 months (2009). Nonetheless, some areas of Uganda have relatively high coverage rates of IRS. For instance, in mid-northern Uganda at least 32 percent of the households had received IRS by 2009 (UBoS and IFC Macro 2010). During the implementation of the 2010/11-2014 UNMCSP, the GoU intends to scale up IRS to 24 of the mostly highly malaria endemic districts of Uganda (MoH 2010a). Nonetheless, one major challenge constraining the expansion of IRS in Uganda is the cost. Estimates by MoH indicate that Uganda requires US$ 500 million to reach every household with IRS in the malaria endemic districts and this particular resource requirement is about 30 percent more than the entire annual budget of the MoH—projected at US$ 390 million in the 2011/12 financial year (Ministry of Finance Planning and Economic Development (MoFPED) 2011). As such, universal coverage of IRS at the moment appears out of reach for Uganda.

Apart from vector control there have been other important malaria control initiatives in Uganda. In 1998, the MoH introduced the Intermittent Preventive Treatment of Malaria in Pregnancy (IPTp). This initiative advocated for the provision of at least two doses of *Sulfadoxine/Pyrimethamine* (SP) to expectant mothers during the routine antenatal visits. The doses are supposed to be received during the second trimester (4-5 months) and third trimester (6-7 months). The first Health Sector Strategic Plan (HSSP I) for Uganda targeted 60 percent utilization of IPTp by 2004; however, over the past 10 years this target has never been met. By 2009, only 32 percent of expectant mothers had taken at least 2 doses during pregnancy while 45 percent had taken at least of one dose for IPTp—despite a very high usage of antenatal services (UBoS and IFC Macro 2010). A number of reasons have been advanced for the limited uptake of this particular malaria control initiative. They range from the fear that the drugs will affect the foetus to stock out of SP and irregular antenatal visits (Ndyomugenyi and Katamanywa 2010). More recently, a USAID backed project under the US President's Malaria Initiative (PMI) has made efforts to train 2,300 health workers on the implementation of this initiative as well as provide public health facilities with cups and safe water to ensure that IPTp usage is directly observed during antenatal visits (President's Malaria Initiative Uganda 2010).

Some of the achievements of Uganda's malaria control programmes in the past 10 years include the reduction in the malaria Case Fatality Rate (CFR) from 5 percent in 1999 to 4 percent by 2010[4]. The 2010-2015 UMCSP has set an ambitious target to reduce the malaria CFR to 2 percent by 2015. Other notable achievements include the 20 percent reduction in malaria outpatient cases registered during 2005/06 and 2009/10 (MoH 2010a). The UNMCSP 2010/11-2014/15 has an ambitious goal to reduce by 50 percent the morbidity and mortality levels attributable to malaria—based on the 2010 levels. This will be achieved by: increasing to 85 percent by 2015—both the proportion of households with access to a LLIN and the proportion of infants sleeping under a LLIN.

In summary, Uganda has implemented a number of malaria control programmes—in some cases with ambitious targets that the country has failed to attain during 15 years of implementing malaria control programmes. With the exception of the recent mass roll out of LLINs, achievements in other malaria control programmes have been lukewarm. At the same time, Uganda requires vast resources in order to achieve universal coverage of malaria prevention. Given the country's limited financial resources, it is important to understand which programmes are most cost effective. In this study, we focus on LLINs and IRS—as these are most widely used malaria control programmes targeting infants in Uganda (a demographic group with the highest incidence of malaria in Uganda). Also as earlier mentioned, it is for only this demographic group that nationally representative information of malaria incidence is available (based on blood tests in the laboratory). In the next section,

[4] Although this change appears small given the 11 year duration, it must be interpreted in the context of Uganda's stagnated health indicators during the 2000s.

we describe the datasets and the methods used to assess the cost effectiveness of LLINs and IRS in Uganda.

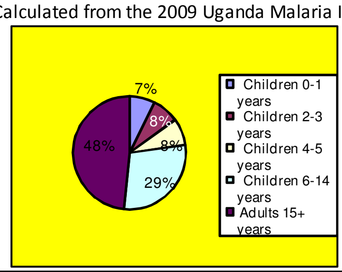
3. Data and methods

3.1 Data

For the data, we rely on the 2009/10 Uganda Malaria Indicator Survey (UMIS) as the basis for epidemiological information on Malaria among infants in Uganda. This survey, conducted by IFC Macro and UBoS is part of the global efforts supported by the US government to examine progress in disease control in developing countries. The 2009 UMIS is nationally representative covering 4,421 households containing 20,637 individuals—of which 22 percent were aged 5 years and below. The survey has the advantage of conducting both RDT for malaria as well as microscopy laboratory tests for malaria pathogens—for all children aged 5 years and below. In the analysis, we rely on results from the microscopy laboratory tests—and not based on either self assessed symptoms of malaria or RDTs—to generate age-specific information on malaria incidence. The survey also has the added advantage of capturing information on whether the child slept under a LLIN in the previous night before the survey and whether the child is resident in a household that received IRS in the past 12 months. We use the UMIS to establish the typical demographic profile of infants in a representative Ugandan district as well as acquire age-specific malaria incidence rates for children aged 5 years and below.

Apart from the demographic and epidemiological information, the other information required for the analysis is the costs of providing the two interventions. The studies by Kolaczinski *et al*. (2010) and Research Triangle International (2008) provided detailed information on the costs of LLINs and IRS (see section 3.2 for detailed description of the costs considered). Other information required related to: case fatality rate and the efficacy of the two interventions in preventing the transmission of malaria parasites. The case fatality rate was based on the figures quoted in the current UNMCSP (2010-2015) while the efficacy rates for both LLINs and IRS were acquired from the 2009 World Malaria Report by the WHO. Table 2 shows the details of the data used and the specific sources. On the other hand, Table A1 in the appendix provides the details of the costs considered in delivering LLINs and IRS in Uganda.

Table 2: Description of the data used in the analysis

Demographics of Study Area (Uganda)		
	Average	**Source/Notes**
Total population for 2 districts (typically 100,000 households)	500,000	population growth rate of 3.0%, this gives a 2010 population of 31.8 million. An average district has about 50,000 households with an average household size of 5.
Estimated population aged 5 years and below	113,500	Based on the 22.7% share of infants in the 2009 Uganda Malaria Indicator Survey.
Age structure of the population		Calculated from the 2009 Uganda Malaria Indicator Survey (UMIS).
Children 0-1 years	0.074	
Children 2-3 years	0.076	
Children 4-5 years	0.077	
Children 6-14 years	0.2878	
Adults 15+ years	0.4843	
Epidemiological Information		
Overall malaria incidence for children 5 years and below (per 1000)	447	From the 2009 Malaria Indicator Survey (Uganda Bureau of Statistics and ICF Macro, 2010)
Malaria incidence by age (per 1000)		
Children under 1	244	
Children 1 year	267	
Children 2 years	385	
Children 3 years	452	
Children 4 years	495	
Children 5 years	532	
Malaria Case fatality rate < 5 years (%)	4.00%	Uganda Malaria Control Strategic Plan 2010/11-2014/15 (Ministry of Health,
Efficacy of LLITNs in reducing malaria	0.63	World Malaria Report 2009 (World Health Organisation, 2009)
Efficacy of Indoor Residual Spraying	0.75	
Cost of delivering LLINs and IRS		
Average cost of delivering LLINs	$6.20	Kolaczinski *et al* ., (2010) See table A1 for details of costs considered
Average cost of delivering IRS per household	$15.60	Research Triangle International (2008)
Average cost of malaria treatment per case in public health facilities	$1.67	Uganda Malaria Control Strategic Plan 2010/11-2014/15 (Ministry of Health, 2010a)
Other data used		
Discount rate	3%	Guess
LLINs coverage rates		
Children under 1	34.50%	Percentage of children who slept under a LLIN last night as reported in 2009 Uganda Malaria Indicator Survey (Uganda Bureau of Statistics and ICF Macro, 2010)
Children 1 year	31.80%	
Children 2 years	32.10%	
Children 3 years	32.80%	
Children 4 years	29.60%	
Children 5 years	28.40%	

3.2 Methods

In order to undertake cost effectiveness analysis between LLINs and IRS, we consider two representative districts of Uganda with a population of 100,000 households (about 500,000 individuals). Based on the demographic profile in the 2009 UMIS dataset, such districts would on average have 22 percent of the individuals aged 5 years and below. The policy objective is to determine which of either LLINs or IRS leads to a higher reduction in the burden of malaria among infants in Uganda for a specified cost. Following Goodman *et al*. (2001), our outcome measure is the estimated number of confirmed cases of malaria among children aged 5 years and below. As earlier mentioned, during the 2009 UMIS, blood samples were collected from this particular demographic group and subjected to rapid diagnostic tests as well as confirmatory microscopic laboratory testing. We utilize the results of the microscopic tests to generate our outcome variable of malaria incidence. Based on the prevailing malaria incidence as well as the specific malaria control programme efficacy rates by WHO, we calculate the number of malaria cases averted by using LLINs or IRS. Also, the incidence of malaria coupled with Uganda's malaria CFR helps provide an estimate of the expected number of deaths due to malaria. Based on the WHO efficacy rates for LLINs and IRS, we estimate the number of malaria deaths averted as result of using any of the two interventions as this is also used as the other outcome variable.

We rely on secondary sources for our cost data. For LLINs, we consider the costs for: training health workers; district sensitization; procurement of LLINs; transportation and storage of nets at the district. The previous study Kolaczinski *et al*. (2010)—which assessed the cost effectiveness of targeted health campaigns and ANCs in delivering LLINs in Adjumani and Jinja districts in Uganda—provides the base for costs used in the current study (see Table A1 in the appendix for the various costs considered). We adopt the average cost reported in this particular study for delivering LLINs (US$6.2). With regard to costs of IRS, we adopt the costs estimated by Research Triangle International for potential roll out of IRS covering in Apac and Oyam districts in Northern Uganda (Research Triangle International 2008). The average cost for delivering IRS per household was estimated at US$ 15.6 in 2007. The other costs considered relate to the costs of illness avoided as a result of accessing any of the two interventions. Due to data limitations, we only consider the cost of malaria drugs avoided or saved due to using either intervention. We adopt the average public cost of malaria treatment of US$ 1.67 as reported by MoH (MoH 2010b).

The cost effectiveness of LLINs and IRS was evaluated by comparing the incremental costs per malaria case prevented by using LLINs compared to IRS. The analysis considered both gross costs as well as net incremental costs after accounting for the cost of malaria illness avoided. In addition, we also performed sensitivity analysis to ascertain the impacts of varying particular parameters e.g. reduction in Uganda's malaria case fatality rate; increases in the costs of LLINs; and the surge in LLINs utilization rates envisaged in current UNMCSP (2010-2015).

4. Results

The results for the cost effectiveness analysis are presented in Table 3. First, it is indicated that the estimated number of malaria cases averted by using LLINs in the two districts is 8,783 while the estimated number of cases averted by using IRS is 33,625. Consequently, the estimated number of deaths averted by using IRS instead of LLINs is 24,843. Second, based on Uganda's malaria CFR of 4 percent, the predicted number of deaths averted by using IRS instead of LLINs is 1000. Third, the calculations for the gross incremental cost effectiveness ratios show that the use of IRS instead of LLINs would cost an additional US$28 per case. On the other hand, the gross incremental cost per death averted is US$702. If we consider the cost of illness avoided, the net incremental cost per malaria case averted would be US$5.8 while the net incremental costs per death averted would reduce to US$660. Finally, the additional malaria cases averted lead to an average cost of malaria illness avoided of US$ 0.37 per case leading to a net cost per case averted of US$ 26.

As earlier mentioned, we undertake sensitivity tests for the parameters used in our analysis. Due to data limitations and empirical tractability, we only undertake one way sensitivity analysis i.e. we only vary one parameter as we hold the base values constant. The results are presented in Table 4 for four potential scenarios: doubling access and utilization of

LLINs; increase in the cost of importing and delivering LLINs; reduction in the incidence of malaria; and the reduction in the malaria case fatality rate in Uganda. First, we consider the doubling of LLINs utilization rates as envisaged in the 2010-2015 UMCSP. This would increase the gross cost per case averted by about 25 percent to US$ 35 while the gross costs per death averted would increase by 30 percent to US$912. The impact of increasing the price of LLINs by 18 percent (Uganda's inflation rate in July 2011)—although IRS would remain more costly than LLINs even in this case—would increase both the gross costs per case averted as well as per death averted by 15-17 percent. However, the most dramatic impacts are registered if we reduce the average incidence of malaria to incidence levels similar to areas of the country with least incidence—South Western Uganda. The reduction of the average incidence of malaria to 116 per 100,000 would increase the gross cost per case and death averted by about 275 percent.

Nonetheless, the above results should be interpreted with caution—especially the fact we only undertake one-way sensitivity analysis. For example, we vary the price of LLINs assuming that the costs of IRS are constant. However, given the fact that both LLINs and IRS are imported into Uganda it is inconceivable that the price of one intervention can rise while the other remains unaffected.

Table 3: Calculations of incremental cost effectiveness of LLINs Vs IRS (US$)

Average malaria incidence among infants in the 2 districts/1000 with LLINs	447
Adjusted rate ratio	0.61
Population of infants in the two districts	113,500
Number of malaria cases in the 2 districts if using LLIN	8,783
Estimated number of cases if IRS has been used in LLIN areas	33,625
Number of malaria cases averted by using IRS instead of LLINs	24,843
Average case fatality rate for malaria in Uganda, %	4
Predicted death averted	1,003
Gross incremental cost per person for LLIN over 1 year period, US$	6.2
Gross incremental cost for infants in the 2 districts for LLINs over 1 year period, US$	703,700
Gross cost per case averted, US$	28
Gross cost per death averted, US$	702
Average treatment cost per patient, US$	1.67
Estimate cost of treatment avoided, US$	41,487
Per capita drug cost per person over 1 year period, US$	0.37
Net incremental cost per person over 1 year period, US$	5.83
Net incremental cost for the two districts, US$	662,213
Net cost per case averted, US$	26.66
Net cost per death averted, US$	660

Table 4: Sensitivity analysis

Variations tested	Gross (US$)		
	Incremental cost over 1 year	Cost per case averted	Cost per death averted
Base case	*6.2*	*28*	*701*
Scenarios:			
a) Utilization rates for LLINs doubles (Approx. utilisation rates for children in households with LLINs	6.2		
b) Increase in price of LLINs by 18% (annual inflation rate in Uganda in July 2011)	7.3	33	807
c) Average baseline malaria incidence reduces from 424 to 116/1000 (lowest incidence registered in South Western Uganda in 2009	6.2	105	2,615
d) Case fatality rate reduced from 4% to 2% (target 2010 under the Uganda National Malaria Control Strategic Plan)	6.2	28	945

Source: Author's own calculations

5. Conclusions

This paper set out to assess the cost effectiveness of LLINs and IRS as malaria control programmes in Uganda. Based on demographic data from the 2009 UMIS, the results show that IRS is significantly more effective in preventing malaria among children aged 5 years and below—with an incremental cost per child covered of US$28 per year and gross cost of US$ 701 per death averted. The one-way sensitivity analysis reveals that our results are most sensitive to changes in the malaria incidence.

However, the results should be interpreted with some limitations in mind. For example, for the cost of illness, the paper only considers the costs of malaria drugs without considering other economic costs such as the cost of transportation to the health facility or the opportunity cost of time lost while attending to a sick child due to malaria. Second, the results do not consider other health benefits arising from malaria prevention apart from cases and death averted. For example, IRS in one village would provide externalities to neighbouring communities inform of reduced malaria transmission rates. Third, the paper assumes two representative districts with similar rates of malaria incidence and as such it may not be possible to generalise our results for different parts of the country with differences in malaria incidence rates. Related, the costs of delivering LLINs are bound to be much lower for areas neighbouring the capital Kampala—even for the same level of malaria incidence. Finally, paper assumes that household behaviours remain constant as all the above changes are taking place. It is possible to increase the effectiveness of LLINs through proper and regular use unlike the present case where some individuals have nets but may not use them.

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Table A 1: Details of inputs, quantities, and costs associated with implementing Long Lasting Insecticide Nets (LLIN) and Indoor Residual Spraying (IRS)

	LLIN Campaign Delivery			**Indoor Residual Spray**		
	Unit	Quanity	Unit Cost (US$)	Unit	Quanity	Unit Cost (US$)
Central training	Per person/per day/per district	1	67			
District Training	Per person/per day/per district	3	221			
Sub county training	Per person/per day/per sub county	3	575			
District sensitization	Per day/per district	1	271			
Sub country sensitization	Per day/per sub county	1	387			
Other sensitization (District Health Officer)	Per day/per district	1	86			
Other sensitization (District Health Officer: Posters)	Per district	12994	948			
Management office costs	Per day/per district	9	1225			
LLIN purchase	Per net	12,994	24,169			
Transportation and strorage at the district	Per net	1	798			
Registration	Per day	2	1508			
Distribution	Per day	4	2015			
Post distribution follow up	Per day	4	441			
Sub Total			32711			
Over head						
Procurement (5%)			1,636			
General (18%)			5,888			
Total			40,235			
Total project cost per LLIN (i.e delivery +net)			6.19			
Total cost per LLIN delivered (i.e excl cost of net)			0.67			
IRS for 100,000 households (about 2 geographic districts in Uganda)						
Cost of routine IRS operations without insecticide				Per household	100000 households @US$10.7	1,070,000
Cost of procuring DDT sachets for lamba-cyhalothrin (ICON CS)				2 households per sache	50000 sachets @ US3.6 each	230,000
Cost of shipment by freight				Per sachet	"@.91 per sachet	
Sub Total (purchasing DDT and conducting routine IRS)						1,300,000
Additional costs measures specific to the use of DDT						
Construction of evaporation tanks				Per district	9 sites per district @US$ 500	9,000
Environmental monitoring						
Soil				5% of villages	$20/Sample, repeated 3 times in a yea	174,420
Export Commodities				5 commoditeis	$10/Sample, repeated 3 times	24,000
Soil, Sediment and Biological Samples in Sensitive Habitats				20 samples	$175 per sample	16,000
Recovery and disposal of DDT packaging				Per sachet	$.23 per sachet	11,500
Market Inspectors				6 Inspectors and 3 drivers)		9,500
Media relations (specilaist, radio spots, and press kits)						16,350
IRS Spray Card						1,500
Sub total additional measures specific to DDT						262,270
Total estimated costs of using IRS with DDT in 2 districts						1,562,270
Average cost per household						15.6

Sources: The costs of LLIN campaign delivery are from Kolaczinski *et al*., (2010) and costs for IRS are from RTI International (2008).