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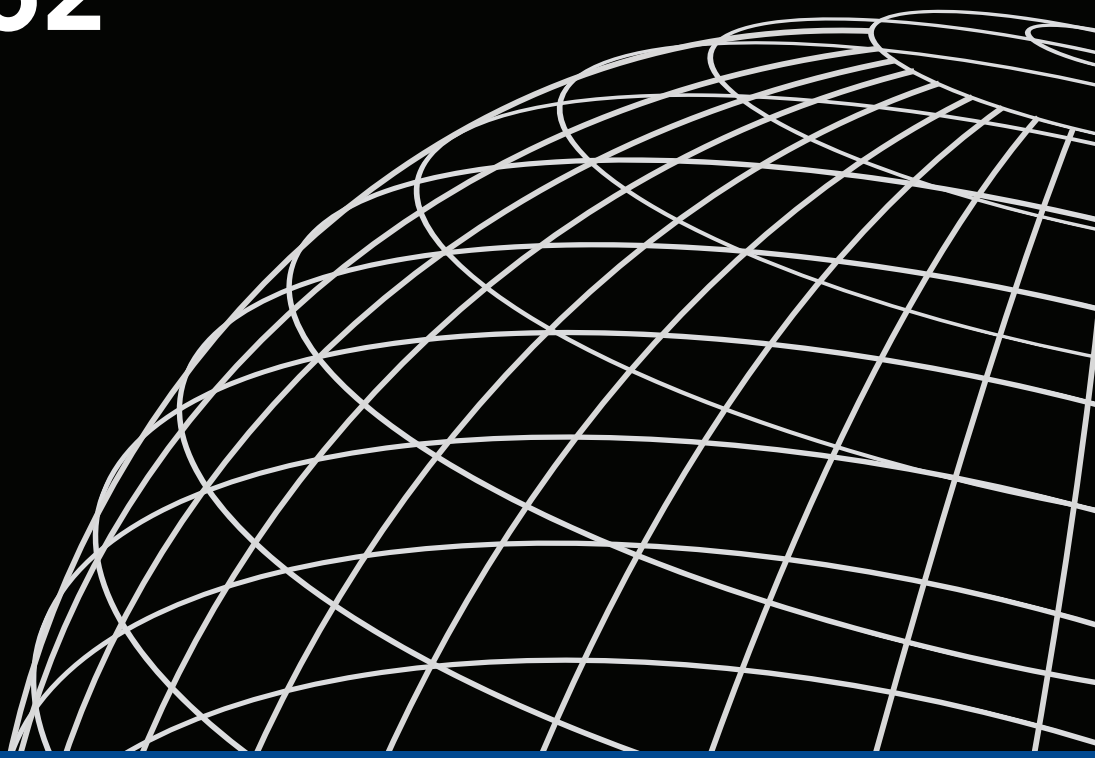
INCREASING EQUITY OF INSECTICIDE-TREATED NET OWNERSHIP IN SUB-SAHARAN AFRICA FROM 2003 TO 2014

DHS ANALYTICAL STUDIES 52



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Increasing Equity of Insecticide-Treated Net Ownership in Sub-Saharan Africa from 2003 to 2014

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Preface

The Demographic and Health Surveys (DHS) Program is one of the principal sources of international data on fertility, family planning, maternal and child health, nutrition, mortality, environmental health, HIV/AIDS, malaria, and provision of health services.

One of the objectives of The DHS Program is to analyze DHS data and provide findings that will be useful to policymakers and program managers in low- and middle-income countries. DHS Analytical Studies serve this objective by providing in-depth research on a wide range of topics, typically including several countries and applying multivariate statistical tools and models. These reports are also intended to illustrate research methods and applications of DHS data that may build the capacity of other researchers.

The topics in the DHS Analytical Studies series are selected by The DHS Program in consultation with the U.S. Agency for International Development.

It is hoped that the DHS Analytical Studies will be useful to researchers, policymakers, and survey specialists, particularly those engaged in work in low- and middle-income countries.

Sunita Kishor
Director, The DHS Program

Abstract

An increase in funding for malaria control in the past decade has resulted in a dramatic increase in ITN ownership and use in sub-Saharan Africa (SSA). There is a need to ensure equal access to the benefits of ITNs across socioeconomic groups. Using data from the Demographic Health Surveys (DHS) and Malaria Indicator Surveys (MIS), this study assesses change in disparity in ITN ownership among households from different socioeconomic groups between baseline (2003-2008) and endline (2009-2014) periods. The analysis compared Lorenz Concentration Curve (C-Curve) and Index (C-Index) values over time to assess changes in economic equity both at the individual country-level and pooled across all countries. Results show evidence of increasing equity in household ownership of at least one ITN by household wealth between baseline and endline periods. In 14 of 19 nineteen countries analyzed, ITN ownership either became more equitable or maintained equity between baseline and endline. Pooled analyses substantiated findings that the rapid and significant increase in ITN ownership has reduced or removed the previous bias that favored wealthy households. Findings from this study support the hypothesis that increased ITN coverage has been accompanied by reduced socioeconomic inequity in ITN ownership over the past 10 years.

Executive Summary

Background

Insecticide-treated bed nets (ITNs) are highly effective in reducing malaria morbidity and mortality [1]. The increase in funding for malaria control in the past decade has resulted in a dramatic increase in ITN ownership and use in many countries in sub-Saharan Africa (SSA). With the shift in programmatic focus from target populations to universal coverage, there is a need to ensure equal access and use of ITNs for all subpopulations regardless of their socioeconomic status. This report examines the change in equity of ITN ownership among malaria endemic countries in SSA from 2003-2014.

Methods

Using data from the Demographic and Health Surveys (DHS) and Malaria Indicator Surveys (MIS), the study assesses the change in disparity in ITN ownership among households from different socioeconomic groups in both country-level and pooled multi-country analyses. Socioeconomic status is assessed with survey-specific assets-based wealth indices categorized into quintiles. Countries included in the analysis had at least two national household surveys with ITN data between 2003 and 2014. The analysis compared Lorenz Concentration Curve (C-Curve) and Index (C-Index) values over time to assess changes in economic equity.

Results

Study results show evidence of increasing equity in household ownership of at least one ITN by household wealth between baseline and endline periods. In 14 of 19 nineteen countries analyzed, ITN ownership either became more equitable or maintained equity between baseline (2003-2008) and endline (2009-2014). In Senegal and Madagascar, ITN ownership favored the poorest households at both baseline and endline while in Mozambique, Angola, and Niger, the inequity in ITN ownership that favored wealthy households remained stable or increased. Multi-country pooled analyses substantiated findings that the rapid and significant increase in ITN ownership has reduced or removed the previous bias that favored wealthy households.

Conclusions

Since 2003, there has been tremendous improvement in the scale up of ITN ownership across SSA. However, with the shift in programmatic focus from high-risk target groups to universal coverage, there is a need to ensure equal access to ITNs for all subpopulations regardless of socioeconomic status. Findings from this study support the hypothesis that increased ITN coverage, achieved through mass distribution campaigns, has reduced socioeconomic inequity in ITN ownership over the past 10 years.

1. Background

1.1. Insecticide-Treated Nets (ITNs)

Individual use of a bed net treated with insecticide is one of the best possible forms of personal protection in malaria-endemic areas. In addition to the physical barrier of the net that reduces human-vector contact at the individual level, the insecticide impregnated in the nets kills or reduces the longevity of mosquitoes and thereby prevents transmission. This overall reduction in transmission provides a "community effect" by which even those residents not sleeping under a net have increased protection from malaria infection [2-5].

In April 2008, Roll Back Malaria (RBM) officially launched the universal coverage campaign with the goal of reducing 2000 levels of malaria deaths by 50% by 2010 and reducing malaria deaths to near zero by 2015 [6]. The target for this campaign was that by 2010, 80% of those at risk from malaria should be using locally appropriate vector control such as ITNs and indoor residual spraying (IRS) [7]. Since the launch of RBM's universal coverage campaign, countries have achieved high ITN coverage levels by utilizing a variety of distribution channels such as community delivery, routine services, or outreach activities. The end goal was having every household at risk of malaria transmission and every person within the household protected by an ITN [8, 9].

Prior to the launch of universal coverage of ITNs in 2008, many distribution strategies focused on populations at high risk of adverse health outcomes due to malaria, typically young children and pregnant women. The ITN policies frequently included distribution to children under age 5 during routine vaccination campaigns and distribution to pregnant women during antenatal care visits advertised via social marketing. This distribution approach benefited children and pregnant women who had access to health services. In addition, ITNs can be purchased either at health facilities or in the private market. Historically, those with greater access to health facilities (urban populations) were more likely to own ITNs than those with low access (rural populations) [5, 10]; less poor households were more likely to own ITNs than the poorest households [5, 11, 12]. With the shift from targeted distribution to universal coverage, malaria control programs have adopted mass distribution campaigns with the potential to significantly increase ITN ownership and provide more equitable coverage of high-risk groups [13-19].

Currently, most National Malaria Control Program (NMCP) policies include mass ITN distributions designed to reach every household in malarious areas and provide one ITN for every two household members or "full population coverage". This assumes that nets are available to 100% of the population and that at least 80% of those with access will use the net each night [20]. The campaigns are recommended every three years based on the longevity of the nets and the cost effectiveness of conducting a mass distribution as compared to a targeted net replacement [20]. While rapid scale up of ITNs has been successful in achieving high population coverage, questions remain about the sustainability of gains in the post scale up phase. After highly effective mass distribution campaigns, additional nets are almost immediately needed for mop-up (for those missed by the distribution) and to address demographic changes (immigration, births, deaths) and replacement of older nets [21]. While mass distribution campaigns are implemented predominately through a top-down and centrally-driven approach, it is likely that the "keep-up" or maintenance process will be driven from the district or community level (bottom-up) [20]. Proper implementation of continuous or maintenance distribution mechanisms are essential for achieving and maintaining equity in ITN coverage.

1.2. Malaria Inequities

For decades, equity in health has been a major tenet of global development organizations, such as the World Health Organization (WHO) and the World Bank, whose policies aimed to decrease the poor-rich gap as a priority. The WHO defines health inequity as "inequality with respect to health determinants, access to the resources needed to improve and maintain health or health outcomes [22]." Unfortunately, many diseases, such as malaria, are not distributed equitably among populations; malaria disproportionately afflicts poor, rural populations, with pregnant women and young children at highest risk of severe morbidity and mortality [5, 23-30]. The many underlying causes of this inequitable distribution include factors such as climate, infrastructure, socioeconomic conditions, access to health facilities, and availability of commodities.

Addressing those inequities that are actionable, such as the availability of commodities, has been the cornerstone of malaria control efforts for the more than a decade. Early assessments of ITN intervention distributions showed low intervention coverage levels [31] and high levels of inequity with poor households disproportionately disadvantaged [5, 12, 32]. Logically, increasing efforts to reach these high burden populations would seem to be the solution; however, several researchers have concluded that meaningful reductions in the malaria burden will require coverage of entire populations, not just those at highest risk [19]. Thus, the new adoption of universal ITN coverage policies should, in theory, reduce health inequities related to malaria. This study provides an opportunity to assess progress made towards these reductions during the several years after widespread implementation of universal coverage programs.

1.3. Malaria Endemicity

Patterns of malaria transmission are influenced by a myriad of factors such as those that operate on small spatial and temporal scales. Thus, disease distribution can be heterogeneous in space as well as over time. While access to malaria control interventions is obviously necessary for use, perceptions of risk also play a role [33, 34]. Many studies investigating ITN use have shown patterns of seasonal use correlated with periods of mosquito nuisance or periods of intense heat [35-38]. Past studies have shown that malaria endemicity and seasonality factors should be considered when examining drivers of ITN ownership [39]. Because of heterogeneous transmission among countries and limited resources, national malaria control programs have historically focused interventions on high transmission areas, which are frequently concentrated in rural locales. However, with the increase in funding for malaria control and the policy shift to universal coverage, many countries are now including areas of intermediate and low risk in their control programs. This shift in focus could influence equity of ITN ownership by increasing the number of less poor households that receive ITNs.

2. Methods

2.1. Data

The following data come from the Demographic and Health Surveys (DHS) and Malaria Indicator Surveys (MIS), which are nationally representative, population-based household surveys that collect information on a wide range of demographic and maternal and child health indicators. All survey data are available at www.dhsprogram.com. This analysis focused on malaria-endemic countries in SSA that have conducted nationally representative household surveys which collected data on malaria interventions between 2003 and 2014 (Figure 1). Baseline surveys were conducted between years 2003-2008 and endline surveys between years 2009-2014. We used the terms baseline and endline to describe the two time periods but it should be noted that each survey was independently sampled. See Annex Table A.1 for further survey details.

Figure 1. Countries with survey data included in analyses

Analysis included a country-level equity analysis as well as a pooled equity analysis. Specific inclusion criteria for the country-level equity analysis included:

1. Countries must have had two surveys conducted from 2003-2014 with accessible data.

2. One survey must have been conducted between years 2003-2008 (baseline) and the other survey conducted between years 2009-2014 (endline).

3. All surveys must have included data on ITN ownership via a bed net roster in the household questionnaire.

In total 19 countries (45 surveys) were selected for country level equity analysis (Table 1).

Table 1. Countries included in country-level equity analysis

Country	Baseline Surveys (2004-2008)	Endline Surveys (2008-2013)
Angola	2006-07 MIS	2011 MIS
Benin	2006 DHS	2011-12 DHS
Burkina Faso	2003 DHS	2010 DHS
Cameroon	2004 DHS	2011 DHS/MICS
Congo (Brazzaville)	2005 DHS	2011-12 DHS
Congo(DR)	2007 DHS	2013-14 DHS
Guinea	2005 DHS	2012 DHS/MICS
Madagascar	2008-09 DHS	2011 MIS 2013 MIS
Malawi	2004 DHS	2010 DHS 2012 MIS
Mali	2006 DHS	2012-13 DHS
Mozambique	2007 MIS	2011 DHS
Niger	2006 DHS	2012 DHS
Nigeria	2008 DHS	2010 MIS 2013 DHS
Rwanda	2005 DHS	2010 DHS 2013 MIS
Senegal	2005 DHS 2008-09 MIS	2010-11 DHS
Sierra Leone	2008 DHS	2013 DHS
Tanzania	2004-05 DHS 2007-08 THMIS	2011-12 THMIS
Uganda	2006 DHS	2009 MIS 2011 DHS
Zimbabwe	2005-06 DHS	2010-11 DHS

The pooled equity analysis examines households by malaria risk. To classify households into a risk zone, it is necessary to obtain the global positioning system (GPS) location of household clusters. In the pooled analysis, countries and surveys were included if the GPS location data for the surveyed clusters were publically available. Specific inclusion criteria for the pooled country-level equity analysis included:

1. Country/survey was included in country-level analysis.

2. Countries had a survey in the baseline and endline period with publicly available GPS data.

3. If a country had more than one survey with GPS data in a time period, only one survey (either the earliest survey or the latest survey) was included in the analysis.

In total, 15 countries (30 surveys) were included for analysis (Table 2).

Table 2. Countries included in pooled equity analysis

Country	Baseline Surveys (2004-2008)	Endline Surveys (2008-2013)
Angola	2006-07 MIS	2011 MIS
Burkina Faso	2003 DHS	2010 DHS
Cameroon	2004 DHS	2011 DHS/MICS
Congo(DR)	2007 DHS	2013-14 DHS
Guinea	2005 DHS	2012 DHS/MICS
Madagascar	2008-09 DHS	2013 MIS
Malawi	2004 DHS	2012 MIS
Mali	2006 DHS	2012-13 DHS
Nigeria	2008 DHS	2013 DHS
Rwanda	2005 DHS	2010 DHS
Senegal	2005 DHS	2010-11 DHS
Sierra Leone	2008 DHS	2013 DHS
Tanzania	2007-08 THMIS	2011-12 THMIS
Uganda	2006 DHS	2011 DHS
Zimbabwe	2005-06 DHS	2010-11 DHS

2.1.1. Indicator

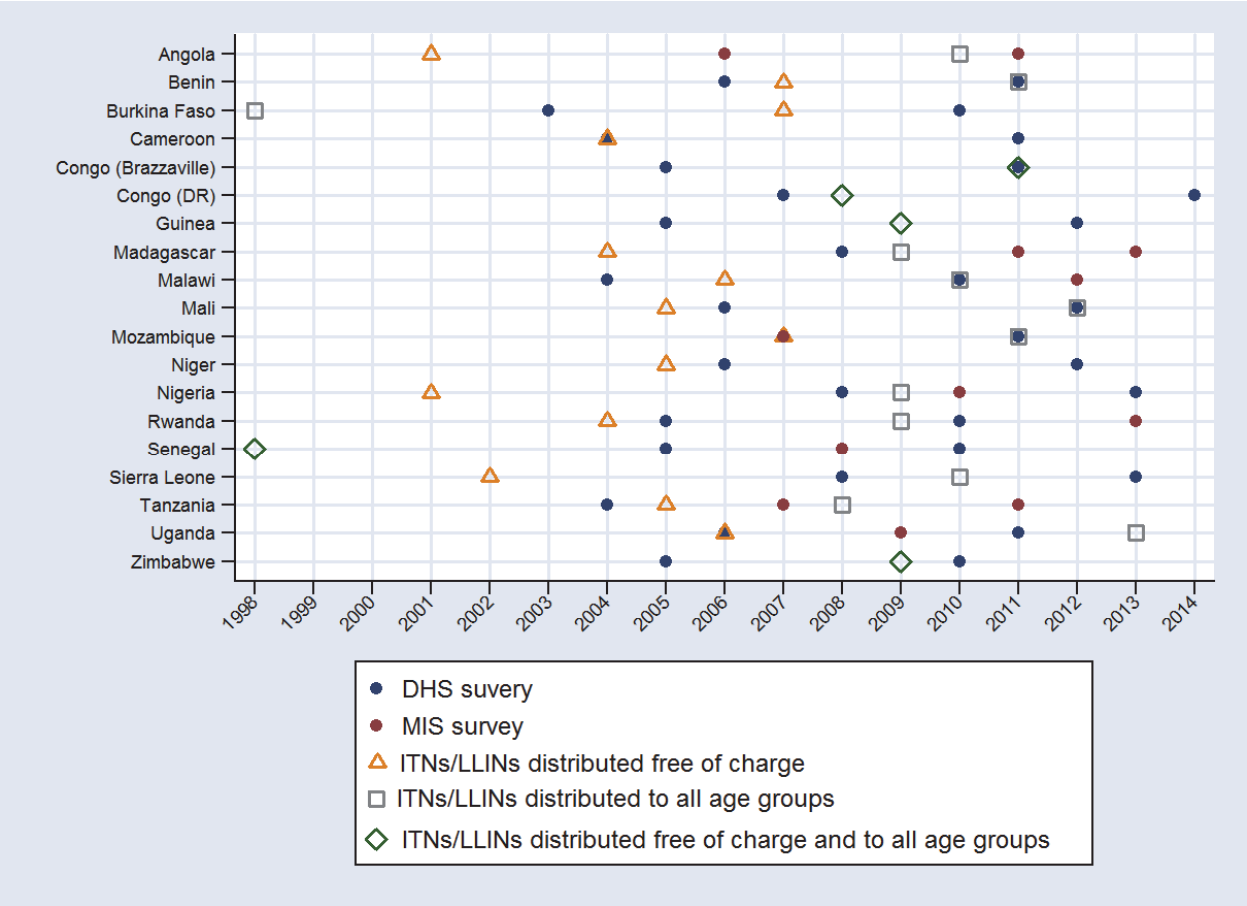
The outcome of interest in this analysis is the proportion of households with at least one ITN which measures household ITN ownership. During the interview with the head of household or other household representative, questions focused on the availability of mosquito nets for use while sleeping and whether each net has been treated with insecticide. This indicator provides a measure for household ownership of an ITN. The indictor reflects the extent to which ITN programs have reached all households or, conversely, the proportion of households not yet reached [40]. While many older surveys (pre-2003) included questions on possession of bed nets, most did not include a bed net roster with detailed questions on the number, types, and characteristics of nets within the household. Without this information, it is not possible to determine which bed nets within the household were treated with insecticide. For this reason, surveys occurring before 2003 could not be included in the analysis.

The proportion of households with at least one ITN was calculated for each survey in the analysis. To test for significant changes in ITN ownership between baseline and endline surveys, 95% percent confidence intervals (95% CI) were calculated with non-overlapping intervals used as evidence of significant differences between surveys.

2.1.2. Timing of ITN campaigns

The timing of national ITN distribution campaigns can greatly influence ITN ownership estimates in nationally representative surveys. Information on the timing of national level ITN distributions in relation to DHS surveys can be difficult to obtain, particularly for surveys conducted between 2003 and 2008, before mass campaigns to all age groups were common mechanisms of distribution. Figure 2 outlines the timing of ITN policies/strategies as reported in the World Malaria Report 2014 [41]as well as the dates of data collection of the DHS and MIS surveys in the analysis. This figure presents a general overview of when policies/strategies were enacted in relation to the fieldwork dates for the surveys. However, this should be interpreted with caution since policy enactment does not always equate to the timing of implementation in the field; there are often delays between the time when a policy becomes official and when the infrastructure and funding are available for implementation. For many countries included in the analysis, the policy shift from targeted distribution to universal ITN distribution campaigns occurred during this period which included free distribution of nets to all age groups.

Figure 2. Timeline of ITN/LLIN strategies and survey data points



Data Source: World Malaria Report Country Profiles 2014 [41] and DHS Program Website www.dhsprogram.com

2.1.3. Wealth quintiles

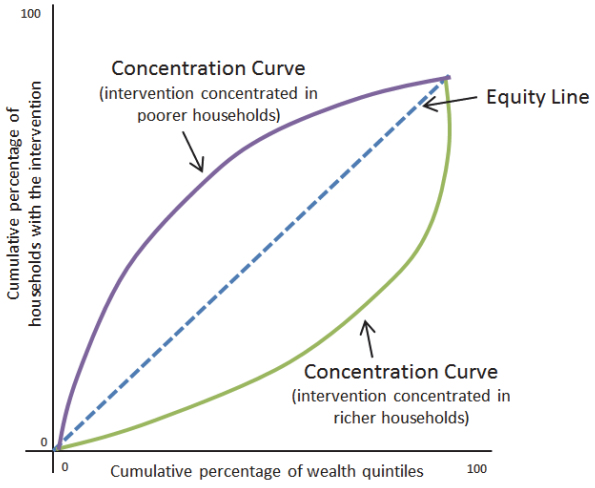
Wealth is a household characteristic that often has a large effect on health [42]. The DHS wealth index is designed to measure economic well-being of households independently from health and education[43]. The DHS wealth index is a survey-specific measure of the relative economic status of households based on analysis of household assets and service amenities at a particular point in time. This measure is particularly valuable in countries which lack reliable data on income and expenditures [44]. The wealth index places individual households on a continuous scale of relative wealth generated by using principal components analysis. Wealth quintile ranking indicates relative rather than absolute economic status of the household [42]. To compare the influence of wealth on various population and health indicators, DHS separates all interviewed households into five wealth quintiles (lowest, second, middle, fourth, and highest) [42, 44, 45]. The wealth index is presented in the DHS Final Reports and included in survey datasets as a background characteristic.

As the economic status of the population in a country improves and household services and assets become more widely available and affordable, a household in the top quintile in an earlier survey could rank in the bottom quintile in a later survey [43]. In another words, wealth status is not directly comparable across surveys and countries. This study, however, is not affected by this limitation because it focuses on the disparities in ITN ownership between the wealthy and the poor only within each survey. Regardless of the survey period or economic variability in country, if ITN ownership is equitable, those concentrated in the lowest wealth quintile should have ownership of ITNs equal to the individuals in the richest wealth quintile. For this reason, this report will not be using a comparative wealth index but will instead calculate equity based on the household wealth quintile for each particular survey.

2.1.4. Equity calculation

We used the Lorenz Concentration Curve (C-Curve) and the Lorenz Concentration Index (C-Index) to assess equity in household ITN ownership across household wealth quintiles. The C-Curve graphically presents the degree of socioeconomic related inequality in a health variable and the C-Index provides quantification of this measure [46, 47]. The x-axis of the concentration curve graphs the cumulative percentage of the sample, ranked by wealth, beginning with the poorest [46]. On the y-axis the concentration curve graphs the cumulative percentage of the health variable/intervention corresponding to the cumulative percentage of the distribution of wealth [46]. C-Index values range between -1 to 1. A value of 0 suggests no difference in ownership and use among different socioeconomic groups. A concentration index of more than 0 suggests that the outcome is more prevalent among the rich. Conversely, a negative index indicates that the outcome is more concentrated among the poor. In context of the C-Curve, the dashed 45-degree line represents equity whereby the health outcome is equally distributed among all wealth quintiles. If the concentration curve is below the equity line (C-index>0), the health outcome is concentrated in richer households; if the concentration curve is above the equity line, the health outcome is concentrated in poorer households (C-index<0) (Figure 3). The

Figure 3. Illustration of the use of the concentration index as a measure of equity



C-Index provides a measure of equity across all five quintiles that is relatively independent of the overall level of coverage [12, 48].

Analyses were conducted with Stata13 software using the *concindc* command for calculating the C-Index and standard errors to measure economic inequalities in ITN ownership. The concentration curves were produced with the *clorenz* command. Ninety-five percent confidence intervals (95%) were calculated for C-Index values. Non-overlapping intervals were used as evidence of significant differences in equity between surveys.

It is important to note that for binary variables (such as ITN ownership), the minimum and maximum potential C-Index values depend on the mean ITN ownership in the country. As the mean increases, the range of potential values of the C-Index is reduced; this places bounds on the possible values of the C-Index [48]. Since the bounds of the concentration index are narrower for higher means, it is suggested that when making comparisons across countries with different means, it is important to express the concentration index as a fraction of the relevant bound [48]. To account for these issues, Erreygers [49] and Wagstaff [48] have developed corrections to the C-Index for bounded binary variables; however, these have been challenged by further research that shows that there are actually few technical differences between the indices [50]. No corrections were applied in these analyses since the goal was not to compare/rank C-Index values by country.

2.1.5. Malaria endemicity

In order to explore if equity in ITN ownership varies by level of malaria transmission, the multi-country pooled equity analysis categorized all survey clusters into categories of malaria risk. Household clusters were assigned a "malaria transmission risk zone" based on *Plasmodium falciparum* parasite prevalence rates among children to 2-10 years (*Pf*PR_{2-10}) from the Malaria Atlas Project (MAP). The MAP provides a spatial data layer that describes the estimated proportion of 2-10 year olds in the general population infected with *Pf* at any one time, averaged over the 12 months of 2010 [51]. The DHS and MIS data include geospatial data for the location of the centroid of each cluster; this permits linkage of survey clusters to MAP data. Using the centroids, all households in a cluster from the DHS or MIS survey data were assigned the same malaria risk value based on corresponding MAP data[52]. Standard MAP *Pf*PR_{2-10} cut-offs were used for analysis:

- No Risk: *Pf*PR_{2-10} <0.1%
- Low Risk: 0.1% > *Pf*$PR_{2-10} \leq 5\%$
- Intermediate Risk: 5%> *Pf*$PR_{2-10} \leq 40\%$
- High Risk: *Pf*PR_{2-10} >40%

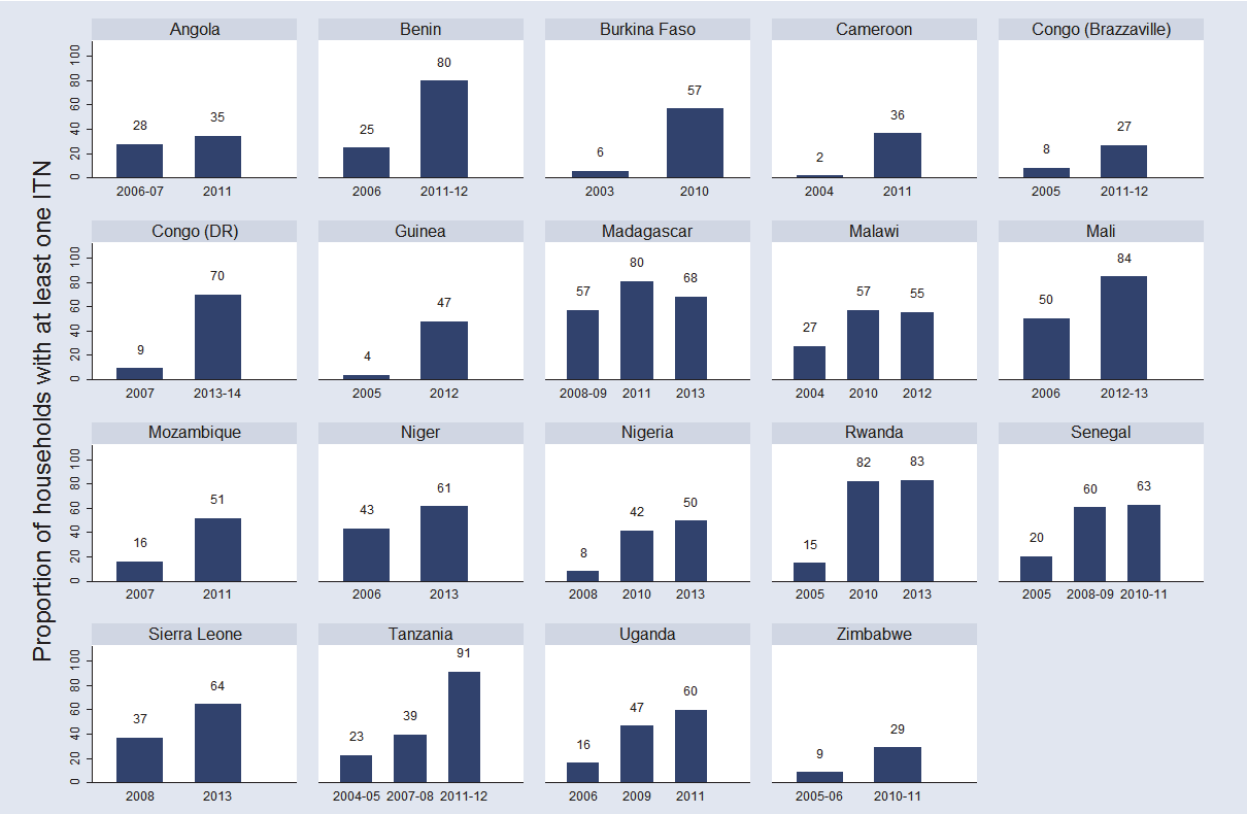
Out of the 346,272 pooled household clusters located in 15 countries, 50% were categorized in the high-risk category (*Pf*PR_{2-10}>40%), 36% in the intermediate risk category (≥5%-40%), 10% in the low risk category (0.1%-5%) and 4% in the no risk category (<0.1%). Clusters located in areas with no risk of malaria (*Pf*PR_{2-10}<0.1%) were excluded from analyses because populations in these areas would not be targeted by ITN distribution campaigns. Due to small sample size in the low risk group, intermediate and low risk categories were combined to comprise 46% of the pooled household clusters; 50% of the pooled household clusters comprised the high risk group.

3. Results

3.1. Descriptive Analysis

In all countries, except Angola, there was a statistically significant increase in ITN ownership between the baseline and endline surveys. The greatest improvement in ITN ownership was seen in both Tanzania and Rwanda where ownership increased by 68 percentage points. Smaller improvements in ITN ownership between baseline and endline surveys were seen in Angola (7%, non-significant increase) and Madagascar (11% increase) (Figure 4). See Table A.3 for 95% confidence intervals.

Figure 4. Proportion of households with at least one ITN by country and survey year



The distribution of ITN ownership by household wealth quintile is seen graphically in Figure 5. The x-axis shows the proportion of households with at least one ITN and the y-axis the survey years for each country. Patterns in ITN ownership by household wealth are represented by colored dots with purple representing the lower wealth quintiles (more poor) and green dots representing the higher wealth quintiles (less poor) populations. Patterns in ITN ownership by household wealth have changed between baseline and endline surveys. ITN ownership in baseline surveys was more frequently concentrated in the highest (richest) quintiles. In the endline surveys we see less evidence of inequality with a smaller range of ITN ownership estimates between wealth quintiles (the purple and green dots are closer together). In some countries, endline surveys show inequity in the opposite direction, with households in the lower wealth quintile with the highest coverage of ITN ownership (Congo (Brazzaville) and Senegal, for example). One notable exception to the pattern of increasing equity between the poorest and the least poor households over time is seen in Angola. Unlike patterns in other countries, the baseline survey in Angola shows higher ITN

ownership among the poorest wealth quintiles as compared to the least poor. This pattern reversed by the endline survey in which the least poor households owned more ITNs than the poorest. Wealth index values can be found in the Annex Table A.2.

Figure 5. Proportion of households with at least one ITN by wealth quintile

3.2. Country-level Equity Analysis

At the country level, concentration curves and C-Index values show improvements in equity of ITN ownership between baseline and endline surveys (Figure 6 and Table 3). For Burkina Faso, Democratic Republic of Congo (DR Congo), Malawi, Rwanda, and Uganda, we see significant improvements in equity between the baseline (2003-2008) and endline (2009-2014) surveys. During the baseline survey the concentration curve falls far below the equity line (C-Index>0), which indicates that ITN ownership is concentrated in the richer quintiles; by the endline survey, these countries' concentration curves had significantly improved (C-Index scores were closer to zero with non-overlapping 95% confidence intervals compared to values from baseline surveys). In Benin, Cameroon, Mali, and Tanzania, equity in ITN ownership across wealth quintiles (C-Index=0) had been achieved by the time of the endline survey.

Congo (Brazzaville), Guinea, Nigeria, Sierra Leone, and Zimbabwe had inequitable ITN distributions that favored richer households at baseline; at the endline survey, ITN ownership was more concentrated in poorer households (concentration curve located above the equity line and C-Index<0 with non-overlapping 95% confidence intervals).

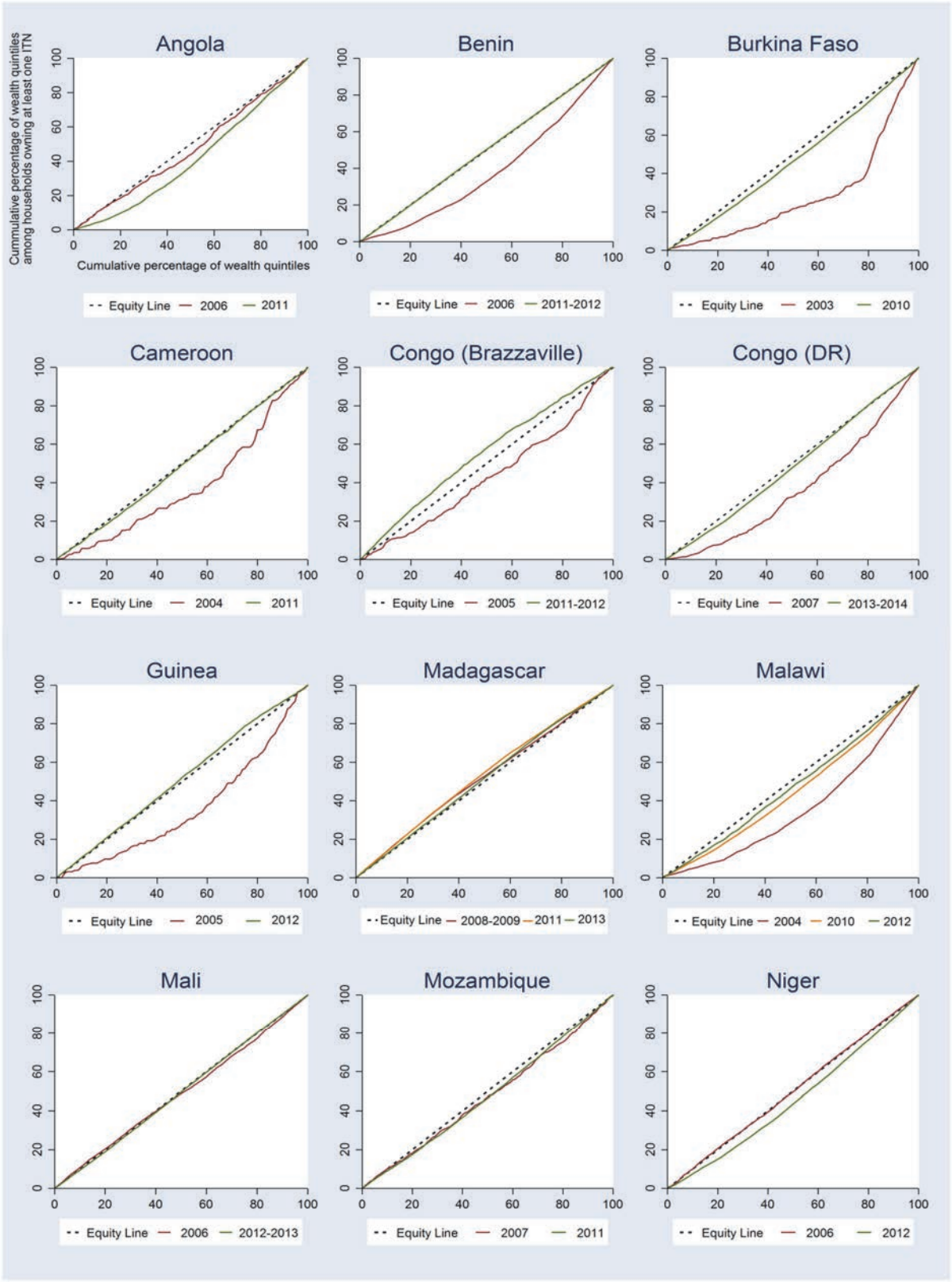
Mozambique maintained levels of inequity from baseline to endline surveys that favored wealthier households. Madagascar and Senegal maintained levels of inequity from baseline to endline surveys that favored the poorest households. Angola and Niger showed increased inequity in household ITN ownership

between wealth quintiles from baseline to endline surveys that favored the wealthiest households (Table 3. Household ITN ownership, concentration index value and 95% CIs, by survey and Figure 6). Table 4 shows a summary of equity changes from baseline to endline surveys categorized by country.

Table 3. Household ITN ownership, concentration index value, and 95% CIs, by survey

Country	Survey Type	Year of Survey	Concentration Index	95% Confidence Interval	
				Low	High
Angola	MIS	2006-07	0.05	0.01	0.08
	MIS	2011	0.17	0.15	0.18
Benin	DHS	2006	0.23	0.21	0.24
	DHS	2011-12	0.00	-0.01	0.00
Burkina Faso	DHS	2003	0.45	0.40	0.49
	DHS	2010	0.06	0.05	0.06
Cameroon	DHS	2004	0.25	0.17	0.33
	DHS/MICS	2011	0.02	0.00	0.03
Congo (Brazzaville)	DHS	2005	0.15	0.10	0.20
	DHS/MICS	2011-12	-0.11	-0.12	-0.09
Congo (DR)	DHS	2007	0.26	0.23	0.30
	DHS	2013-14	0.03	0.03	0.04
Guinea	DHS	2005	0.28	0.21	0.35
	DHS/MICS	2012	-0.03	-0.04	-0.02
Madagascar	DHS	2008-09	-0.04	-0.04	-0.03
	MIS	2011	-0.06	-0.07	-0.05
	MIS	2013	-0.03	-0.04	-0.02
Malawi	DHS	2004	0.29	0.28	0.31
	DHS	2010	0.11	0.10	0.11
	MIS	2012	0.06	0.04	0.07
Mali	DHS	2006	0.02	0.01	0.03
	DHS	2012-13	0.01	0.00	0.01
Mozambique	MIS	2007	0.05	0.02	0.08
	DHS	2011	0.04	0.03	0.05
Niger	DHS	2006	0.00	-0.02	0.01
	DHS	2012	0.09	0.08	0.10
Nigeria	DHS	2008	0.18	0.16	0.20
	MIS	2010	-0.08	-0.09	-0.06
	DHS	2013	-0.06	-0.06	-0.05
Rwanda	DHS	2005	0.36	0.33	0.38
	DHS	2010	0.04	0.03	0.04
	MIS	2013	0.02	0.02	0.03
Senegal	DHS	2005	-0.03	-0.05	0.00
	MIS	2008-09	-0.09	-0.10	-0.08
	DHS	2010-11	-0.11	-0.12	-0.10
Sierra Leone	DHS	2008	0.05	0.04	0.07
	DHS	2013	-0.02	-0.03	-0.01
Tanzania	DHS	2004-05	0.41	0.39	0.43
	THMIS	2007-08	0.22	0.20	0.23
	THMIS	2011-12	-0.01	-0.01	0.00
Uganda	DHS	2006	0.11	0.09	0.14
	MIS	2009	0.01	-0.01	0.03
	DHS	2011	0.02	0.02	0.03
Zimbabwe	DHS	2005-06	0.19	0.15	0.22
	DHS	2010-11	-0.06	-0.08	-0.04

Figure 6. Change in concentration index from baseline to endline survey by country



(Continued…)

Figure 6. – *Continued*

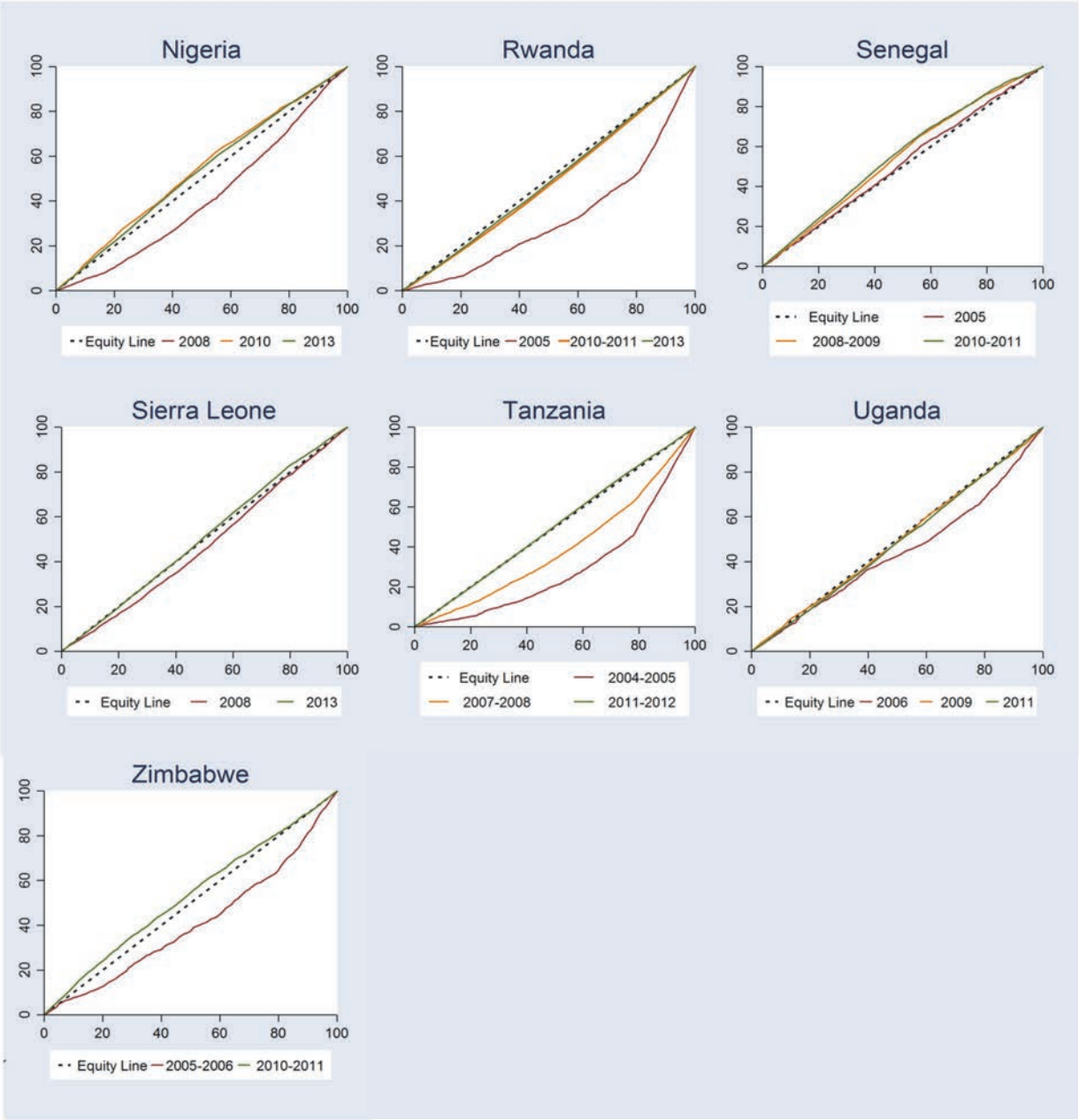
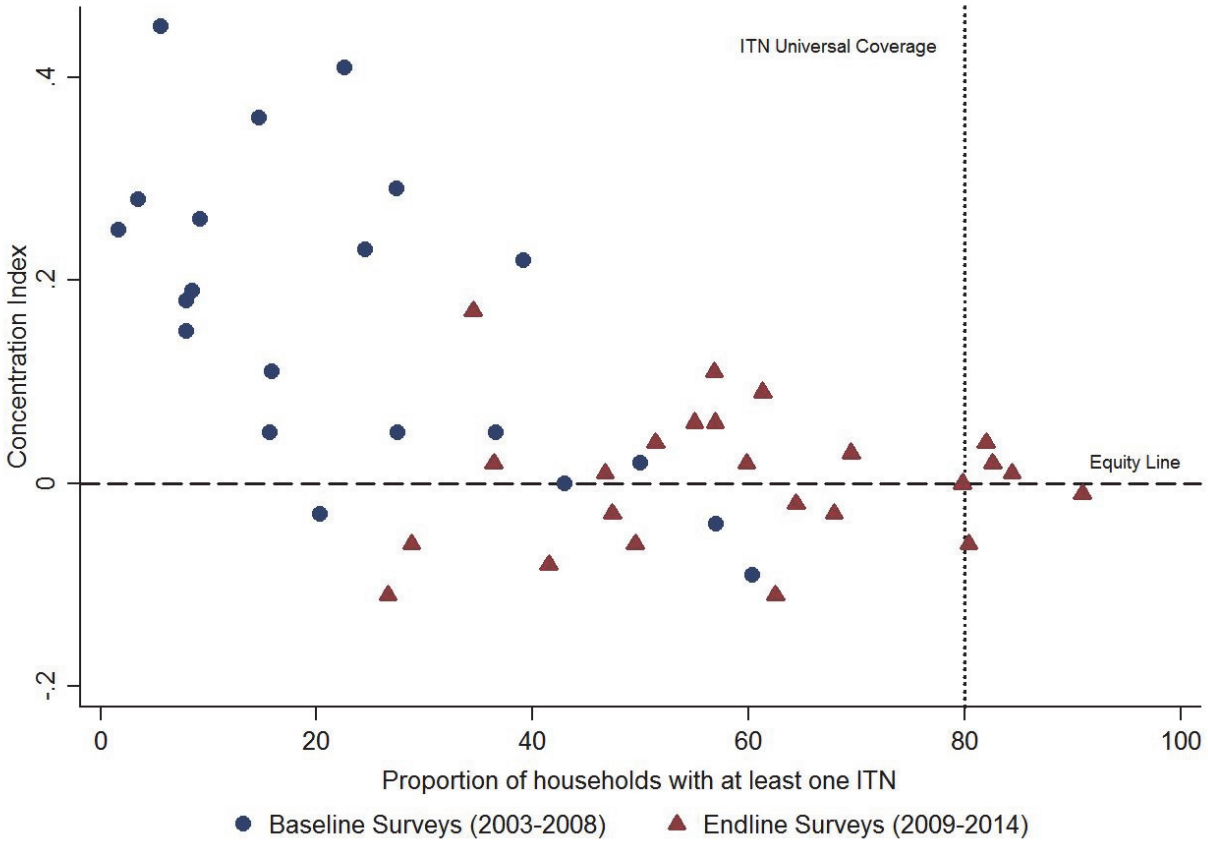


Table 4. Summary of equity changes from baseline to endline surveys

Equity Summary	Countries
Baseline: ITN ownership concentrated in richer households Endline: ITN ownership closer to equity but still concentrated in richer households	Burkina Faso Congo (DR) Malawi Rwanda Uganda
Baseline: ITN ownership concentrated in richer households Endline: ITN ownership equitably distributed	Benin Cameroon Mali Tanzania
Baseline: ITN ownership concentrated in richer households Endline: ITN ownership concentrated in poorer households	Congo (Brazzaville) Guinea Nigeria Sierra Leone Zimbabwe
Baseline: ITN ownership concentrated in richer households Endline: Maintained inequity at baseline levels (no significant change)	Mozambique
Baseline: ITN ownership equitable or concentrated in richer households Endline: Worsening inequity favoring richer households	Angola Niger
Baseline: ITN ownership concentrated in poorer households Endline: ITN ownership concentrated in poorer households	Madagascar Senegal

Figure 7 shows a scatter plot of the concentration index by ITN ownership for all surveys included in the country-level analysis. The figure shows a decline in the variation of concentration index values as ITN coverage increases. This trend is not surprising since high ITN coverage levels are difficult to reach without improving coverage in the poorest households; any ITN ownership levels greater than 80% require at least part of the population in the lowest wealth quintile to own ITNs. Comparing the trends in baseline and endline surveys, we see that surveys that took place from 2009-2014 tend to have higher ITN ownership and greater equity in ITN ownership as compared to surveys from 2003-2008.

Figure 7. Proportion of households with at least one ITN by concentration index

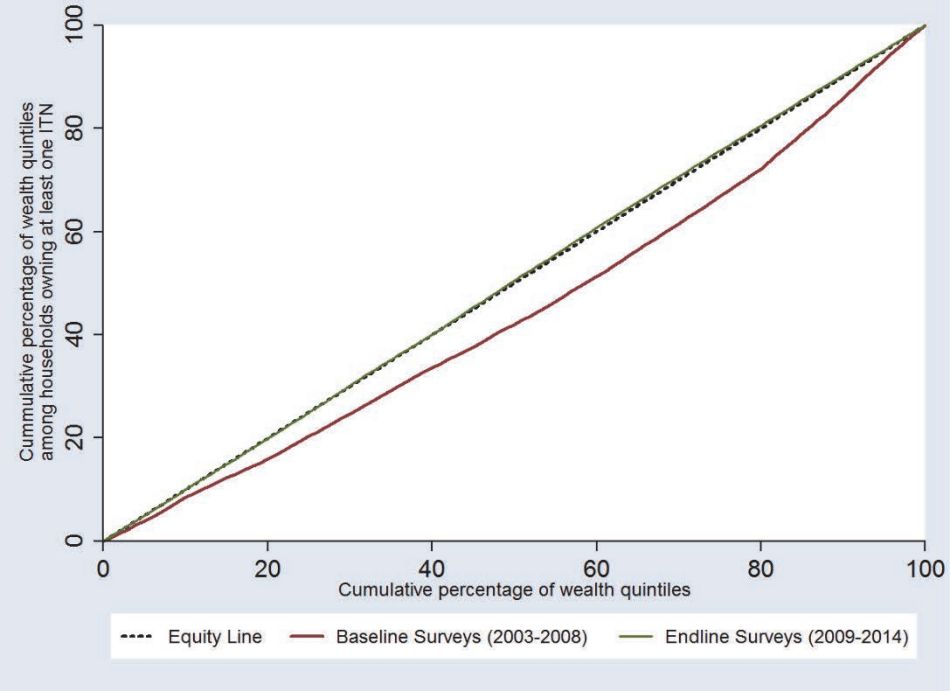


Note: ITN Universal Coverage of 80% is based on the Global Strategic Plan 2005-2015

3.3. Pooled Equity Analysis

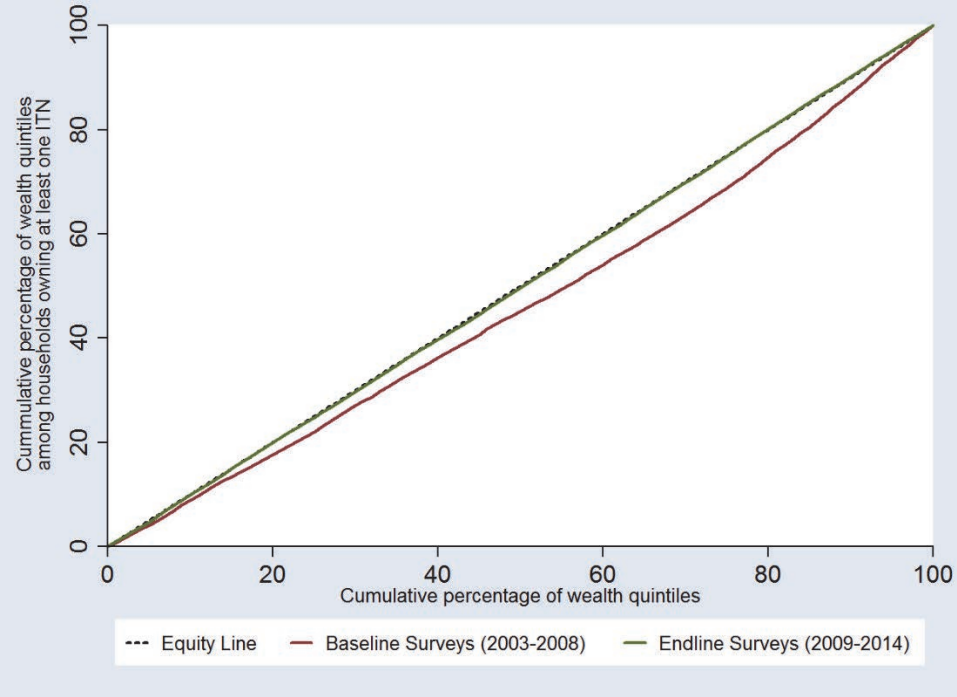
Analysis of all clusters of surveys from the 15 countries included in the multi-county pooled analysis found a significant reduction in wealth inequality between baseline (C-Index 0.11, 95% CI: 0.10; 0.11) and endline surveys (C-Index 0.00, 95% CI: =0.01; 0.00). In surveys conducted between 2003-2008, the concentration curve falls far below the equity line (C-Index>0); this indicates that ITN ownership was concentrated in the richer quintiles, although by 2008-2014 the pooled concentration curve was just at the equity line (C-Index<0) (Figure 8).

Figure 8. Pooled ITN equity (15 countries)



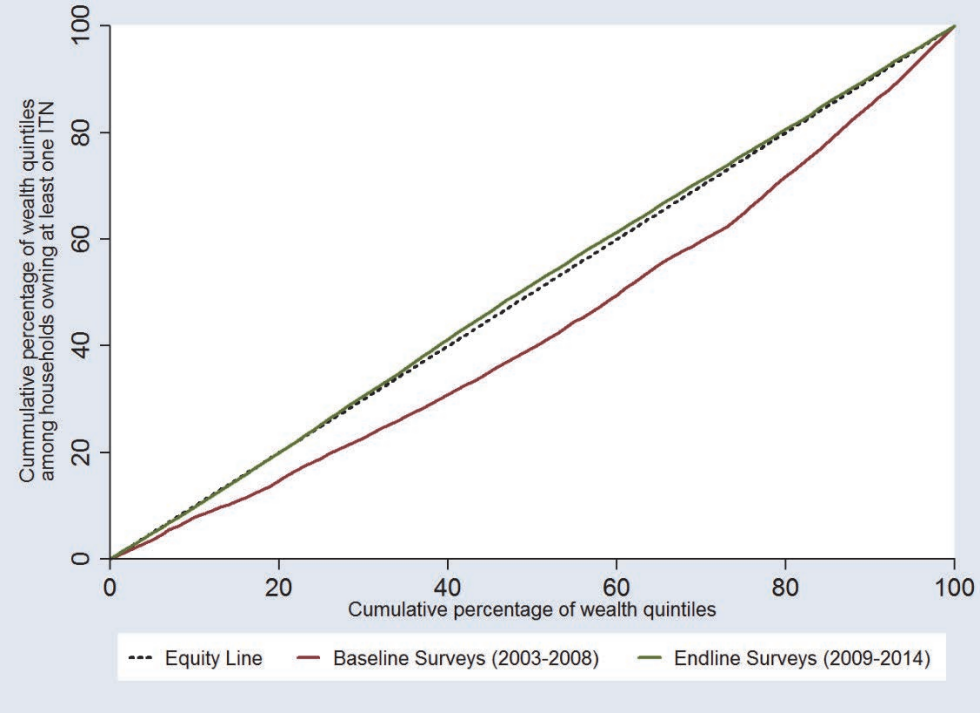
When restricting to clusters located in the high malaria transmission (*Pf*PR_{2-10}>40%) risk zones, we see a similar pattern with ITN ownership concentrated in higher wealth quintiles from 2003-2008 (C-Index 0.07, 95% CI: 0.06; 0.08) and transitioning to a more equitable distribution in 2009-2014 (C-Index 0.00, 95% CI: 0.00; 0.01) (Figure 9).

Figure 9. Pooled equity by high malaria transmission risk (*Pf*PR_{2-10}>40%)



However, when restricting to clusters in the intermediate/low malaria transmission risk zones (*Pf*PR$_{2-10}$ = 0.1%-40%), we see that ITN ownership was concentrated in higher wealth quintiles from 2003-2008 (C-Index = 0.14, 95% CI: 0.13; 0.14) and in poorer households in 2009-2014 (C-Index = -.01, 95% CI: -0.02;-0.01) (Figure 10).

Figure 10. Pooled equity by intermediate/low malaria transmission risk (*Pf*PR$_{2-10}$ 0.1%-40%)



In comparisons of the intermediate/low malaria transmission risk zones (Figure 10) to high malaria transmission risk zones (Figure 9), we see that there was greater wealth inequality in the baseline surveys of the intermediate risk zones (C-Index 0.14) as compared to those located in the high risk zone (C-Index 0.07).This difference was significant at the 95% confidence level. Although both risk zones achieved equity by the endline survey, there was a greater increase in equity between baseline and endline surveys in the intermediate/low malaria transmission risk zones (a difference of 0.15 C-Index values) as compared to the high risk zones (a difference of 0.07 C-Index values).

4. Discussion

The study results show evidence of increasing equity in household ownership of at least one ITN by household wealth between baseline and endline periods. In 14 of 19 countries analyzed, ITN ownership either became more equitable or maintained equity between baseline (2003-2008) and endline (2009-2014). However, in Senegal and Madagascar, ITN ownership favored the poorest households at both baseline and endline. In Mozambique, Angola, and Niger, inequity in ITN ownership that favored wealthy households remained stable or increased. Pooled analyses substantiated the findings that the rapid and significant increase in ITN ownership has not favored the wealthiest households in most settings.

Although the overall trends are clear, the reason for the trends is not as straightforward. In countries with very high levels of household ITN ownership, the chances of equitable distribution are inherently higher (if every household owns an ITN then distribution will necessarily be equitable). Thus, the recent influx of funding for malaria control and the subsequent investment of mass ITN distribution campaigns have likely contributed to improved equity by attaining high levels of coverage. However, a study by Njau and colleagues [53] found little evidence of improved equity in ITN ownership in the comparisons of regions of Angola, Uganda, and Tanzania that had experienced targeted bed net distribution despite significant improvements in coverage. The authors concluded that targeted net distribution strategies may not be sufficient for addressing socioeconomic inequities in access to bed nets and that further analyses were needed to assess equity after the implementation of mass distribution campaigns.

The timing of mass net distributions in relation to the collection of survey data may influence observed trends. Mozambique had a mass ITN distribution campaign the same year as the last DHS. If the survey data were collected before the campaign, we would not expect to see the effects reflected in the equity estimates from the survey. Angola's trend of increasing inequity in ITN ownership could be partially due to the timing of campaigns and an insufficient ITN supply for the population at risk. In 2011, for example, the same year as the baseline survey, ITNs were distributed free of charge but only in specific municipalities where the NMCP's implementing partners were present. Reasons for the trend in Niger are less clear but could be due to geographic and infrastructural challenges with accessing households equally during distribution campaigns. A 2005 ITN distribution campaign linked to a mop-up polio immunization campaign found that the large, widely dispersed, migrant population and the desert terrain made it difficult to reach all targeted individuals [54]. This suggests that, in addition to policy decisions, the geographic and epidemiologic diversity in malarious countries may influence equity of interventions.

The effects of malaria epidemiology on equity of ITN ownership were investigated by pooling clusters into two groups stratified by low/intermediate (PfPR$_{2-10}$ = 0.1%-40%) and high levels (PfPR$_{2-10}$>40%) of malaria transmission. In the pooled analysis of 15 countries, equity increased significantly in both groups; however, the greatest improvement in equity occurred in clusters in the low/intermediate risk zone. The observed results could be due to changing ITN policies between baseline and endline surveys, and more specifically, the rollout of free mass distributions campaigns after 2008. Before 2008, financial and logistic restraints caused most distribution campaigns to be targeted to high-risk populations (children under 5 and pregnant women) and/or high-risk regions (rural, high transmission zones). Those in poorer households in low/intermediate risk zones were less likely to own a net if they did not have access to health services or could not afford to pay for a net at market price. The shift to mass distribution campaigns would have improved equity by providing access to the poorest households that did not have previous access to nets.

Results that show the variation in C-Index values decreased (ITN ownership became more reliably equitable across wealth quintiles) as level of ITN ownership increases are not surprising; inherently, as ITN coverage rises (over 80%) equity will increase. Our results support the conclusion of Kilian and colleagues that equity can be achieved by attaining high levels of ITN coverage with a focus on universal distribution instead of targeted campaigns to address equity [8]. In the future, these strategies may need to be reconsidered. As ITN levels reach saturation and malaria prevalence declines, mass distributions may no longer be cost-effective, and identification of increasingly specific target populations may be necessary.

5. Limitations

This study presents evidence of the positive impact of universal coverage scale up on equity of ITN ownership. However, there are several important limitations. Data used in analyses come from cross-sectional surveys which limits causal inference. Any overlap in survey implementation and ITN distribution may complicate the interpretation of findings. Additionally, it is important to note that this study focused on equity of ITN ownership but did not assess other important factors such as ITN use or ITN access. The use of ITN is essential for protection, except in settings of high community level ITN ownership in which some level of indirect protection is conferred from the insecticidal properties of the nets[4, 55]. Analyses of equity of ITN access (the percent of the population that could use an ITN with the assumption that one ITN can protect two users) would also be informative as it is a more comprehensive measure of the level of protection within a household.

6. Conclusions

Analyzing data from 19 malaria-endemic countries in SSA between 2003 and 2014, this study assessed change in disparity of ITN ownership among different socioeconomic groups by using the Lorenz Concentration Curve (C-Curve) and Index (C-Index) as a measurement of economic equity over time.

Since 2003 there has been tremendous improvement in the scale up of ITN ownership across SSA. However, with the shift in programmatic focus from high-risk target groups to universal coverage, there is a need to ensure equal access to ITNs for all sub-populations regardless of socioeconomic status. These findings support the hypothesis that mass ITN distribution campaigns have increased ITN coverage and reduced socioeconomic inequity in ITN ownership over the past 10 years. Despite the gains observed in coverage of ITN ownership over the past years, further improvements are still needed to reach coverage targets. With the combination of continued net scale up and monitoring inequities, great strides can be made in combating malaria across SSA countries.

Appendix

Table A.1. List of the surveys included in this report, with dates and sample sizes

Country	Survey Type	Year of Survey	Household Sample Size	Fieldwork
Angola	MIS	2006-07	2,599	November 2006 - April 2007
	MIS	2011	8,030	January 2011 - May 2011
Benin	DHS	2006	17,511	August 2006 - November 2006
	DHS	2011-12	17,422	December 2011 - March 2012
Burkina Faso	DHS	2003	9,097	June 2003 - November 2003
	DHS	2010	14,424	May 2010 - January 2011
Cameroon	DHS	2004	10,462	February 2004 - August 2004
	DHS/MICS	2011	14,214	January 2011 - August 2011
Congo (Brazzaville)	DHS	2005	5,879	July 2005 - November 2005
	DHS/MICS	2011-12	11,632	September 2011 - February 2012
Congo (DR)	DHS	2007	8,886	January 2007 - August 2007
	DHS	2013-14	18,171	August 2013 - February 2014
Guinea	DHS	2005	6,282	February 2005 - June 2005
	DHS/MICS	2012	7,109	June 2012 - October 2012
Madagascar	DHS	2008-09	17,857	November 2008 - August 2009
	MIS	2011	8,094	March 2011 - June 2011
	MIS	2013	8,574	April 2013 - June 2013
Malawi	DHS	2004	13,664	October 2004 - January 2005
	DHS	2010	24,825	June 2010 - November 2010
	MIS	2012	3,404	April 2012 - May 2012
Mali	DHS	2006	12,998	May 2006 - December 2006
	DHS	2012-13	10,105	November 2012 - February 2013
Mozambique	MIS	2007	5,745	June 2007 – July 2007
	DHS	2011	13,919	June 2011 - November 2011
Niger	DHS	2006	7,660	January 2006 - May 2006
	DHS	2012	10,750	February 2012 - June 2012
Nigeria	DHS	2008	34,070	June 2008 - October 2008
	MIS	2010	5,895	October 2010 - December 2010
	DHS	2013	38,522	February 2013 - June 2013
Rwanda	DHS	2005	10,272	February 2005 - July 2005
	DHS	2010	12,540	September 2010 - March 2011
	MIS	2013	4,766	February 2012 - May 2013
Senegal	DHS	2005	7,412	February 2005 - May 2005
	MIS	2008-09	9,291	December 2008 - January 2009
	DHS	2010-11	7,902	October 2010 - April 2011
Sierra Leone	DHS	2008	7,284	April 2008 - June 2008
	DHS	2013	12,629	June 2013 - October 2013
Tanzania	DHS	2004-05	9,735	October 2004 - February 2005
	THMIS	2007-08	8,497	October 2007 - February 2008
	THMIS	2011-12	10,040	December 2011 - May 2012
Uganda	DHS	2006	8,870	May 2006 - October 2006
	MIS	2009	4,421	November 2009 - January 2010
	DHS	2011	9,033	June 2011 - December 2011
Zimbabwe	DHS	2005-06	9,285	August 2005 - February 2006
	DHS	2010-11	9,756	September 2010 - March 2011

Table A.2. Percentage of households with at least one insecticide-treated net, by wealth quintile and survey

			Wealth Quintiles				
Country	**Survey**	**Year**	**Lowest (Q1)**	**Second (Q2)**	**Middle (Q3)**	**Fourth (Q4)**	**Highest (Q5)**
Angola	MIS	2006	36.7	18.8	17.5	12.8	14.3
	MIS	2011	7.4	9.6	16.1	34.1	32.9
Benin	DHS	2006	10.0	14	19.8	25.6	30.6
	DHS	2011	21.0	20.5	20.7	19.8	18
Burkina Faso	DHS	2003	6.0	6.7	9.1	11.1	67.1
	DHS	2010	15.5	18	19	20.9	26.6
Cameroon	DHS	2004	7.1	14.3	15.5	26.8	36.3
	DHS/MICS	2011	16.1	20.2	21.6	21.2	20.9
Congo (Brazzaville)	DHS	2005	13.3	16.5	16.5	21.1	32.6
	DHS/MICS	2011	45.7	27.9	11.4	8.4	6.6
Congo (DR)	DHS	2007	11.0	16.1	20.8	22.4	29.7
	DHS	2013	23.5	21.8	21.5	18.8	14.4
Guinea	DHS	2005	10.0	13.7	16.1	25.1	35.1
	DHS/MICS	2012	23.5	19	19.6	23.4	14.6
Madagascar	DHS	2008	22.6	19.5	16.1	17	24.9
	MIS	2011	25.5	17.8	14.7	15.3	26.8
	MIS	2013	18.5	16.7	15.7	15.8	33.3
Malawi	DHS	2004	10.1	15.3	18.8	24.8	30.9
	DHS	2010	16.4	19.4	21.1	21.8	21.3
	MIS	2012	14.5	15.8	16.9	18.5	34.2
Mali	DHS	2006	17.2	19.6	19.5	21.8	21.9
	DHS	2012	18.7	19.8	19.5	19.1	22.9
Mozambique	MIS	2007	17.1	18.4	21.5	20.7	22.3
	DHS	2011	14.2	17.5	20.4	22.3	25.7
Niger	DHS	2006	17.1	17.3	17.5	20	28.1
	DHS	2013	13.8	15.9	17	20.4	32.9
Nigeria	DHS	2008	10.8	16.6	22.2	25.2	25.3
	MIS	2010	20.0	18.8	21.4	20	19.7
	DHS	2013	17.0	20.6	22.9	21.1	18.5
Rwanda	DHS	2005	6.3	12.7	11.7	18.8	50.5
	DHS	2010	19.8	19.6	19.6	19.2	21.7
	MIS	2013	20.2	19.8	18.9	18.8	22.2
Senegal	DHS	2005	16.1	21.8	28.9	18.7	14.5
	MIS	2008	28.3	29.4	20.8	13.6	8
	DHS	2010	31.0	26.7	20.6	13.2	8.5
Sierra Leone	DHS	2008	17.0	16.3	18.4	22.8	25.5
	DHS	2013	20.8	18.8	19.8	22.7	18
Tanzania	DHS	2004	4.9	9.8	14	23.2	48
	THMIS	2007	10.7	14.2	16.9	25.7	32.4
	THMIS	2011	19.9	19.1	19.3	22.1	19.5
Uganda	DHS	2006	20.8	18	11.3	15.6	34.3
	MIS	2009	25.3	17.7	16.6	17.4	23
	DHS	2011	20.1	17.2	16.5	17.4	28.8
Zimbabwe	DHS	2005	13.2	17	14.3	23.2	32.3
	DHS	2010	25.0	17.9	17.8	18.7	20.6

Table A.3. Percentage of households with at least one insecticide-treated net, including 95% confidence intervals, by survey

Country	Survey Type	Year of Survey	Proportion of households with at least one ITN			
			%	LCI	UCI	N
Angola	MIS	2006-07	27.5	23.6	31.8	2,599
	MIS	2011	34.5	31.8	37.3	8,030
Benin	DHS	2006	24.5	23.5	25.6	17,511
	DHS	2011-12	79.8	78.7	80.8	17,422
Burkina Faso	DHS	2003	5.6	4.8	6.6	9,097
	DHS	2010	56.9	55.2	58.6	14,424
Cameroon	DHS	2004	1.7	1.4	2.1	10,462
	DHS/MICS	2011	36.4	34.6	38.2	7,133
Congo (Brazzaville)	DHS	2005	8.0	6.4	10	5,879
	DHS/MICS	2011-12	33.1	31.2	35	11,632
Congo (DR)	DHS	2007	9.2	7.9	10.7	8,886
	DHS	2013-14	69.5	67.6	72.2	18,171
Guinea	DHS	2005	3.5	3.0	4.2	6,282
	DHS/MICS	2012	47.4	45.2	49.6	7,109
Madagascar	DHS	2008-09	57.0	55.0	59.1	17,857
	MIS	2011	80.4	77.0	83.7	8,094
	MIS	2013	68.6	65.4	71.2	8,574
Malawi	DHS	2004	27.4	25.8	29	13,664
	DHS	2010	56.8	55.5	58.1	24,825
	MIS	2012	55.0	51.1	58.9	3,404
Mali	DHS	2006	50.0	47.5	52.6	12,998
	DHS	2012-13	84.4	83.1	85.6	10,105
Mozambique	MIS	2007	15.7	14.1	17.5	5,745
	DHS	2011	51.4	49.5	53.4	13,919
Niger	DHS	2006	43.0	40.4	45.6	7,660
	DHS	2012	61.3	59.4	63.1	10,750
Nigeria	DHS	2008	8.0	7.3	8.6	34,070
	MIS	2010	41.5	37.2	46.0	5,895
	DHS	2013	49.5	47.7	51.4	38,522
Rwanda	DHS	2005	14.7	13.6	15.9	10,272
	DHS	2010	82.0	80.7	83.2	12,540
	MIS	2013	82.6	81	84.2	4,766
Senegal	DHS	2005	20.3	18.9	21.9	7,412
	MIS	2008-09	60.4	57.5	63.3	9,291
	DHS	2010-11	62.5	59.7	66.1	7,902
Sierra Leone	DHS	2008	36.6	34.3	39.0	7,284
	DHS	2013	64.4	62.3	66.6	12,629
Tanzania	DHS	2004-05	22.6	20.7	24.7	9,735
	THMIS	2007-08	39.2	37.0	41.4	8,497
	THMIS	2011-12	90.9	90.1	91.8	10,040
Uganda	DHS	2006	15.9	14.3	17.7	8,870
	MIS	2009	46.7	42.8	50.6	4,421
	DHS	2011	59.8	57.7	61.9	9,033
Zimbabwe	DHS	2005-06	8.5	7.3	9.8	9,285
	DHS	2010-11	28.8	26.0	31.7	9,756

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