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What Has Driven the Decline of Infant Mortality in Kenya?

Gabriel Demombynes
Sofia Karina Trommlerová

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Abstract

Substantial declines in infant and under-5 mortality have taken place in recent years in many countries in Sub-Saharan Africa. Kenya's infant mortality rate has fallen by 7.6 percent per year, the fastest rate of decline among the 20 countries in the region for which recent Demographic and Health Survey data is available. Kenya's rate of postneonatal deaths per 1,000 live births fell by more than half over a five-year period, dropping from 47 to 22, as measured using data from the 2003 and 2008-09 Demographic and Health Surveys. Among the possible causes of the decline are various targeted new public health initiatives and improved access to water and sanitation. A Oaxaca-Blinder decomposition using Demographic and Health Survey data shows that the increased ownership of insecticide-treated bednets in endemic malaria zones explains 39 percent of the decline in postneonatal mortality and 58 percent of the decline in infant mortality. Changes in other observable candidate factors do not explain substantial portions of the decline. The portion of the decline not explained may be associated with generalized trends such as the overall improvement in living standards that has taken place with economic growth. The widespread ownership of insecticide-treated bednets in areas of Kenya where malaria is rare suggests that better targeting of insecticide-treated bednet provision programs could improve the cost-effectiveness of such programs.

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Gabriel Demombynes
World Bank

Sofia Karina Trommlerová
University of Göttingen

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1 Introduction

Infant and under-5 mortality has declined markedly in Sub-Saharan Africa during the last decade. Among the 20 Sub-Saharan African countries that have conducted Demographic and Health Surveys (DHS) since 2005, 18 countries showed improvements in infant survival since the country's previous survey, and broad improvements have taken place in under-5 mortality as well. The Millennium Development Goal for under-5 mortality is a reduction of two-thirds over the 25 year period 1990-2015, which implies an annual rate of decline of 4.4 percent; twelve of the 20 recent DHS countries have rates of decline that exceed this rate. For infant mortality, Kenya stands out among the success stories, with an annual rate of decline of 7.6 percent, the highest among the 20 countries.

The gains in infant mortality are just one element of a wide set of improvements in human welfare in Kenya and many countries in Sub-Saharan Africa. In one review of these changes, Radelet (2010) argues that five fundamental changes have driven the broader turnaround in the "emerging African countries" that he profiles: 1) more democratic and accountable governments, 2) more sensible economic policies, 3) the end of the debt crisis and major changes in relationships with the international community, 4) new technologies that are creating new opportunities for business and political accountability, and 5) a new generation of policymakers, activists, and business leaders. Accompanying these changes has been a new push by governments and the international community to implement public health initiatives, including those advanced by the Gates Foundation, the Global Fund to Fight AIDS, Tuberculosis and Malaria, as well as other organizations.

Millions of dollars have been poured into these initiatives, many of which have been shown to be effective on a small scale in randomized controlled trials. However, given the challenges of governance and large-scale implementation in many countries, the effectiveness of such initiatives on a larger scale is uncertain. The fact that these initiatives were implemented at the same time that broader institutional changes were taking place makes it difficult to draw conclusions as to the source of particular outcomes.

This paper assesses the possible contribution of various factors to the decline of infant mortality in Kenya using a Oaxaca-Blinder decomposition analysis of changes in infant mortality as measured in Demographic and Health Surveys (DHS) conducted in 2003 and 2008. Previous studies such as Rajaratnam et al (2010) have documented the recent declines in mortality of infants and older children, many studies have documented the effectiveness of insecticide-bednet nets (ITN) in preventing malaria (see Lengeler 2004 for a review), and various studies have tracked changes in child survival in response to particular interventions, generally in narrowly defined populations (e.g. Kleinschmidt et al. 2009 and Ndirangu et al. 2010). This paper makes several contributions. First, the Oaxaca-Blinder analysis allows for an analysis which simultaneously considers several possible drivers of the change observed over time. Second, the use of DHS data makes it possible to examine changes for Kenya as a whole. Third, the use of local malaria prevalence data makes it possible to allow for a varying impact of ITNs by malaria prevalence.

The paper is organized as follows. Section 2 of the paper describes patterns in infant mortality in Sub-Saharan Africa. Section 3 presents the changes in infant mortality and the possible set of drivers in Kenya along with an analysis of correlates of infant mortality. Section 4 focuses on the Oaxaca-Blinder analysis. Section 5 considers what these results imply about the cost-effectiveness of bednet interventions, and Section 6 concludes.

2 The Infant Mortality Decline in Sub-Saharan Africa

A broad decline in infant mortality has occurred across Sub-Saharan Africa. Table 1 shows both infant (under age 1) and under-5 mortality for countries with recent Demographic and Health Surveys.[1] The most recent DHS-based estimates indicate infant mortality to be below 100 per 1000 live births in all 20 countries for which post-2005 DHS data is available and to be falling in 18 of those 20 countries. This paper focuses on infant mortality, but similar trends are found for under-5 mortality. Among the 20 countries with recent DHS data, the surveys show average annual rates of decline of 3.6 percent in infant mortality (under age 1) and 4.2 percent in under-5

[1] Data is shown for all countries in Sub-Saharan Africa which have had at least two DHS surveys, including at least one since 2005. Other estimates are available from other surveys as well as composite estimates from the United Nations Inter-agency Group on Child Mortality. We focus on the DHS estimates because they are more clearly comparable over time and across countries than estimates assembled from a mix of sources.

mortality. A recent review of long-term trends in under-5 mortality synthesizing a wide variety of data (Rajaratnam et al 2010) finds that "Rates of decline have increased in 34 countries in Sub-Saharan Africa for 2000-10 compared with 1990-2000 and have increased by 1% or more" in 13 countries, including Kenya.[2] The Rajaratnam et al. analysis was completed before much of the data underlying the figures in Table 1 was available, and the new data shows very rapid recent declines in several countries.

A number of factors may have contributed to the broad decline in infant mortality across Sub-Saharan Africa. One prominent possibility is the decline in malaria prevalence which has coincided with the scaling up of the use of insecticide-treated bednets (ITN) and other anti-malarial interventions, including indoor residual spraying, use of more effective artemisinin-based drugs, and improved diagnostic capacity at health facilities. The decline in malaria in Kenya has been documented in a number of studies, including Okiro et al (2007), Okiro et al (2009), and Okiro et al (2010). Among the interventions which may have contributed to the decline in malaria, growth in ITN usage appears to be most substantial.[3] Several rigorous studies have shown that ITN usage prevents malaria transmission (Lengeler 2004), and one longitudinal study (Fegan et al 2007) of 3500 Kenyan children under age five found that ITN usage was associated with a 44 percent drop in mortality risk. Noor, Mutheu, et al (2009) estimate that the number of African children living in malaria-endemic conditions who were protected by an ITN grew from 1.7 million (1.8 percent) in 2000 to 20.3 million (18.5 percent) in 2007.

Other possible factors include changes in immunization rates, births in medical facilities, antenatal care, and access to safe water and sanitation facilities. Finally, overall economic growth may have played a role, by increasing levels of income, leading to improved nutrition and access to medical care. Over the period 2004-2008, growth rates of GDP per capita averaged 4.3 percent in Sub-Saharan Africa (IMF 2010).

Given that many changes have taken place simultaneously, it is difficult to definitively attribute a causal effect to particular interventions. This paper takes Kenya as a case study to consider the

[2] Although the main analysis of the Rajaratnam et al (2010) paper concerns child mortality, similar findings apply to infant mortality.

[3] Noor et al (2007) describe the various campaigns to distribute ITNs.

possible drivers of the broader drop in infant mortality. We focus on Kenya because the drop in infant mortality was particularly large in Kenya and because available data on the geographic variation of malaria prevalence make it possible to take into account the level of malaria risk in the analysis.

3 The Infant Mortality Decline in Kenya and Possible Drivers

Methods of calculating child and infant mortality can be classified into "direct" methods and "indirect" methods. Direct methods of calculation use data on the date of birth of children, their survival status, and the dates of death or ages at death of deceased children. Indirect methods require less data—number of children ever born and number living, along with age of the mother—but demand much stronger assumptions. There are three principal types of direct methods, which are described as follows in the *Guide to DHS Statistics* by Rutstein and Rojas (2006):

> 1. A vital statistics approach in which the numbers of deaths to children under age 12 months in a particular period are divided by the numbers of births in the same period….
>
> 2. A true cohort life table approach in which deaths to children under age 12 months of a specific cohort of births are divided by the number of births in that cohort. This procedure gives true probabilities of death, but has the drawback that all children in the cohort must have been born at least 12 months before the survey to be fully exposed to mortality, thus not taking into account the most recent experience. This requirement of full exposure becomes more limiting the higher the age segment of interest: For under-five mortality rates, only the information on children born five or more years before the survey can be utilized….
>
> 3. A synthetic cohort life table approach in which mortality probabilities for small age segments based on real cohort mortality experience are combined into the more common age segments.

The tabulations found in DHS reports use the third approach, which is appropriate for producing aggregate mortality rates and maximizing the use of available data. Using this approach, DHS publications present mortality rates calculated for the five years previous to the particular survey in question.

In this paper, we are interested in analyzing the individual and household-level correlates of infant mortality. For this purpose, we work with actual survival data of individuals rather than aggregate figures. This corresponds to the true cohort life table approach. Specifically, we use observations on children born alive 12-35 months before the interview. This analysis uses principally data from Kenya Demographic and Health Surveys (DHS) conducted in 2003 and 2008-09 (hereafter 2008). Given the precise dates of the DHS interviews, the infant survival data is based on a set of births that occurred April 2000-August 2002 and November 2005-February 2008. The sample consists of 2295 observations in the 2003 DHS and 2373 observations from the 2008 DHS. See the Annex for further details on sample restriction and data imputation procedures.

The specific choice of time window for eligible births (12-35 months before the DHS interview) was determined by a number of factors. The period must end 12 months before the survey date so that survival up through the age of one year can be determined for each observation. A time period extending more than 35 months would expand the size of the sample. However, some of the possible correlates for mortality—such as ITN ownership and water and sanitation access—are measured on the date of the survey. Consequently, the reliability of this information as a guide to the circumstances of the infant's first year of life declines as the window for observations is extended into the past. The 12-35 month window was chosen to balance the competing concerns of sample size and relevance of data observed on the date of the survey.

The analysis is restricted to infant mortality and does not examine the broader question of under-5 mortality because under-5 mortality can only be determined for individuals once five years have passed since the child's birth. This means that, for example, an analysis of child survival based on individual data from the 2008 DHS could only use data on births that took place in 2003 or earlier. However, such births would have taken place in circumstances far removed in terms of time from the characteristics of the household (ITN ownership, water and sanitation access, etc.) at the time of the survey in 2008, and the survival of such children would be much less relevant to evaluating post-2003 changes in policies and programs.

Infant mortality, which refers to deaths in the period up to 12 months of age, is comprised of neonatal and postneonatal mortality. Neonatal mortality refers to deaths taking place from birth

up to 28 days of age. Postneonatal mortality deaths are those that occur from age 28 days up to age 12 months. Neonatal and postneonatal mortality rates for a cohort sum up to the infant mortality rate (World Health Organization 2005).

True cohort life table infant mortality estimates calculated with the sample as described above are shown in Figure 1 and Table 2. These estimates differ from the published DHS estimates for the periods 1999-2003 and 2004-2008, because both the time period and the methods differ. The broad trends, however, are similar. The cohort life table estimates show the overall decline in infant mortality was entirely the consequence of a decline in postneonatal mortality and was partially offset by a small and statistically insignificant increase in neonatal mortality. Neonatal deaths increased from 34 to 38 deaths per 1000 live births. Postneonatal mortality fell from 47 deaths to 22 deaths per 1000 live births. Infant mortality declined from 81 to 60 deaths per 1000 live births. These changes correspond to an increase of 12 percent and declines of 53 percent and 26 percent, respectively.[4]

A number of changes took place between 2003 and 2008 in Kenya in factors that could explain the drop in infant mortality. The use of iron supplements during pregnancy, immunization rates, intake of anti-malarial drugs during pregnancy, ITN ownership and usage, and access to improved sanitation and improved source of drinking water rose substantially, as shown in Table 3. A particularly notable change was the growth in ITN ownership. The fraction of households owning at least one ITN increased from 8.3 percent to 60.4 percent nationally.

A change in ITN usage by children would be expected to have an effect on postneonatal mortality but little or no effect on neonatal mortality. This is because the incidence of severe malaria in newborns is low (Snow and Marsh 2002).[5] The basic pattern of neonatal and

[4] This analysis does not closely examine differences in infant mortality by sex of the child. Overall, infant mortality rates are higher for boys than for girls. The trends for boys and girls over time are similar: a large decline in postneonatal mortality but no change in neonatal mortality.

[5] Snow and Marsh (2002) cite past research which suggests that newborns are less susceptible to malaria due to some combination of protection afforded by passively acquired maternal immunoglobulin G, the physiological protection offered through the continued presence of fetal haemoglobin, and riboflavin deficiency. ITN ownership could affect neonatal mortality via ITN usage by pregnant women. According to Snow and Marsh (2002), malaria in pregnancy is associated with low birth weight, which increases both neonatal and postneonatal mortality.

postneonatal mortality across malaria zones reflects this phenomenon.[6] Table 2 shows neonatal, postneonatal, and infant mortality rates by characteristics, pooling data from 2003 and 2008. Neonatal mortality rates are statistically identical across malaria risk zones (approximately 36 per 1000 live births), while postneonatal mortality is lowest in low malaria risk zones (16 per 1000), slightly higher in intermediate malaria risk zones (20 per 1000), and three times as high in high malaria risk zones (62 per 1000).

ITN ownership rates have increased across Kenya, and the postneonatal survival gains have been chiefly in the high malaria risk areas, particularly rural Nyanza province but also urban Nyanza province as well as both urban and rural Western province. Figure 2 shows a scatter plot by province and urban/rural classification of postneonatal mortality rates vs. ITN ownership using the 2003 and 2008 DHS data. Figure 3 shows a similar plot for neonatal mortality. The geography of shifts over time that have taken place in neonatal mortality show no obvious correlation with malaria patterns.

It is important to recognize that the ITN measure used throughout this paper is *household ownership* of at least one ITN at the time of the DHS survey. This differs from actual *usage* of ITNs by individual children. Because information on ITN usage by deceased children is not available, it is not possible to use DHS data to examine the association between ITN usage and mortality. We thus take ITN ownership by the household is used as a proxy for ITN usage. ITN usage by children is highly correlated with the household's ownership of at least on net. In the sample, 82 percent of living children in households with at least one ITN slept under an ITN the night before the interview.

Table 2 summarizes comparisons of neonatal, postneonatal, and infant mortality rates by basic characteristics. As noted, postneonatal mortality is greater in high malaria risk zone and is significantly lower in households that own at least one ITN. This difference is significant both overall and within high malaria risk zones. Postneonatal mortality is also lower for infants from

[6] We categorize survey clusters from the DHS into "low malaria risk zones," "intermediate malaria risk zones," and "high malaria risk zones" using data assembled by the Malaria Atlas Project. The Annex provides a description of this classification. The risk zones are defined in terms of prevalance of Plasmodium falciparum, which is the most deadly strain of malaria and is estimates to be responsible for 98 percent of malaria cases in Sub-Saharan Africa (World Health Organization 2008).

households with access to a source of drinking water other than surface water, in households with some sanitation facility, particularly those with an improved sanitation facility. Children born in a health facility and children living in urban areas show significantly lower postneonatal mortality rates than their counterparts.[7]

Neonatal mortality patterns show few significant differences using bivariate comparisons. Surprisingly, neonatal mortality rates are higher if the child was born in a health facility, and this difference is significant at the 1 percent level. This could reflect a causal effect, perhaps because of higher risk of infection due to exposure of the infant to patients in the facility. It is possible, however, that this represents at least in part a selection effect: women with higher risk pregnancies for which the newborn will face greater mortality risk may be more likely to seek birth in a health facility, and it is also possible that neonatal deaths are more likely to be reported if they take place within a facility.[8] With available data it is not possible to distinguish between these two hypotheses.

Next we analyze the correlates of postneonatal and infant mortality in a multivariate framework using a linear probability model. The dependent variable is a measure of mortality at the individual level, which takes value 1 if the child died during the postneonatal (or infant) period and value 0 if the child survived. Explanatory variables include variables measured at district, household, mother, and individual level. Most of the variables are measured at household level: urban/rural location, province, location in malaria risk zone, ITN ownership, access to drinking water and sanitation, and socioeconomic status as measured by a wealth index. Antenatal care variables (intake of iron supplement, intake of anti-malarial drugs, tetanus vaccination) and mother's educational level are measured for the mother.[9] Whether the child was born in a health facility is measured at individual level. Because vaccination records are not available for deceased children, immunization is measured as the fraction of children with all vaccines at the

[7] All differences described in this paragraph are statistically significant at the 5% level.
[8] Reported neonatal mortality rates are also higher for births to women with tertiary education, although because there are few such births, the confidence interval is large and this difference is only significant at the 10 percent level.
[9] The DHS data on antenatal care was collected for the last birth only. For a child who is not the last birth, its value was approximated by its last born sibling. In the final sample (4668 observations), there are 1046 children (22.4%) who are not the lastborns.

district level. Additionally, a dummy variable for the year of the survey is introduced. (See the Annex for detailed variable definitions.)

Table 4 shows results from various specifications of these regressions for postneonatal mortality. The first column shows the simplest specification, including only a year dummy and dummy variables by malaria risk zone, both alone and interacted with household ITN ownership. Presence in a high malaria risk zone is associated with higher mortality, and presence in a high malaria risk zone combined with ITN ownership is associated with lower mortality. Column (2) includes a measure of immunization, using a district-level full vaccination rate; higher levels of immunization are not significantly associated with a difference in mortality rates. In column (3), whether the birth took place in a facility and the mother's use of three measures of antenatal care—antenatal protection against neonatal tetanus, antenatal anti-malarial drugs, and antenatal iron supplements—are included, and none of the resulting coefficients are significant. Column (4) adds in measures of the source of drinking water and access to sanitation of the household. The use of an unimproved water source (as opposed to surface water) for drinking is associated with lower mortality, but the use of an improved water source shows no difference from surface water. Column (5) includes a measure of mother's education, and column (6) adds dummies for the wealth quintile of the household. Mortality rates show no difference by mother's education, and the patterns by quintile are counter to expectations: controlling for other variables, children of wealthier households have slightly higher mortality rates than those in the poorest quintile. It is important to note that these findings for education and household wealth are from a regressions which controls for many of the channels through which education and wealth are likely to affect mortality. In a simple bivariate comparison (not controlling for other variables), there is a much lower postneonatal mortality risk for children of educated mothers, but no statistically significant difference by wealth.

Finally, the specification in column (7) includes a rural dummy as well as province dummies. There is no significant difference between rural and urban areas, conditional on other explanatory variables. The patterns are consistent across specifications, with one exception: access to improved sanitation is significantly associated with lower mortality in the full specification and not in shorter specifications.

We take the results from column (6), which excludes the rural and provincial variables, as the preferred specification. These results show that living in a high malaria risk zone is associated with a 6.2 percent point greater probability of postneonatal death, while ownership of an ITN in such an area is associated with a 3.8 percent point lower probability of death. They also show that use of an unimproved water source other than surface water for drinking and access to an improved sanitation facility are associated with drops of 2.8 and 2.6 percent point in mortality risk, respectively.

Table 5 presents results from similar regressions for neonatal mortality. A set of specifications parallel to those used for postneonatal mortality is used. Findings are similar across specifications, and we again take the column (6) specification as the preferred specification. None of the ITN ownership and malaria risk zone variables have statistically significant associations with neonatal mortality. The multivariate analysis shows the similar pattern for facility births seen in the bivariate comparison: neonatal mortality is 3 percent higher for births reported in a facility. As noted earlier, this could be a causal effect of facility births, a selection effect if problematic pregnancies are more likely to result in births in facilities, or possibly better reporting of neonatal deaths if they take place in facilities. The table also shows that controlling for other factors, children born to the small number of women with tertiary education have neonatal mortality rates which are 7 percent higher. This puzzling finding, however, is only statistically significant at the 10 percent level. Because only 4.3 percent of the observations in our sample have mothers with tertiary education, this result is particularly sensitive to reporting errors and biases. While we cannot determine conclusively from available data, it is possible that this finding reflects greater reporting of neonatal deaths among more educated women.

Table 6 presents the results of the analysis for infant mortality, which is the sum of neonatal and postneonatal mortality, so that these results reflect a combination of the patterns seen in the analysis for postneonatal and neonatal mortality. Column (6) again shows the results from our preferred specification. The results for presence in a high malaria risk zone and ITN ownership are similar to those for postneonatal mortality alone: living in a high malaria risk zone is associated with a 7.6 percent point greater probability of death, while ownership of an ITN in such an area is associated with a 4.7 percent point lower probability of death. The infant mortality results also show that access to an improved sanitation facility is associated with a 5.5

percent point lower probability of infant death (as compared to no sanitation facility). The infant mortality results show a slightly higher—2.6 percent point—risk of death for an infant born in a facility.

Overall, these regression results point to three factors as candidates for explaining portions of the decline in infant mortality in Kenya: ITN ownership, improved sanitation facilities, and the use of water sources other than surface water. Other candidate factors, including immunization rates and antenatal care, are not significantly associated with improved probability of infant survival.

4 A Decomposition Analysis of the Decline in Infant Mortality in Kenya

In this section, we apply the Oaxaca-Blinder decomposition method to further examine possible drivers of the infant mortality decline in Kenya. The Oaxaca-Blinder approach, introduced by Oaxaca (1973), combines cross-sectional conditional correlations like those presented in the previous section with information on changes in the values of the underlying variables. The approach presents a statistical decomposition of changes in the mean of a variable, in this case the probability of death, measured per 1000 live births. The decomposition is derived starting from the following:

$$\overline{mortality}_{2003} - \overline{mortality}_{2008} = \bar{X}_{2003}'\hat{\beta}_{2003} - \bar{X}_{2008}'\hat{\beta}_{2008}$$

This equation describes the difference in the average number of child deaths per 1000 live births ($\overline{mortality}$) between 2003 and 2008 as a function of the means of explanatory variables $\bar{X}$ and estimated coefficients $\hat{\beta}$. The Oaxaca-Blinder decomposition separates the change into an "explained" and an "unexplained" portion.

$$\overline{mortality}_{2003} - \overline{mortality}_{2008} = \underbrace{(\bar{X}_{2003} - \bar{X}_{2008})'\hat{\beta}_{pooled}}_{explained\ part} + \underbrace{\bar{X}_{2003}'(\hat{\beta}_{2003} - \hat{\beta}_{pooled}) + \bar{X}_{2008}'(\hat{\beta}_{pooled} - \hat{\beta}_{2008})}_{unexplained\ part}$$

Our focus is the explained portion, i.e. changes in the mean of explanatory variables $\bar{X}$ between 2003 and 2008 multiplied by the corresponding coefficients from the pooled cross section $\hat{\beta}_{pooled}$. The explained portion can be decomposed further into a sum of contributions of each of the respective explanatory variables. For categorical variables with more than 2 categories, all

categories are included in the decomposition and the contributions are expressed as deviations from the grand mean following the procedure suggested by Jann (2008). The following analysis is based on the specifications shown in columns (6) of Tables 4, 5, and 6, which do not include the rural or province dummies.

The decomposition results are shown in Table 7. They suggest that 39 percent of the observed decline in postneonatal mortality, i.e. 9.7 out of a decline of 24.8 deaths per 1000 live births, can be explained statistically by the increase in ownership of ITNs in high malaria risk zones of Kenya. Changes in the remaining variables do not explain the decline in postneonatal mortality to a significant degree.

The separate decomposition analysis for infant mortality shows a similar result for ITN ownership in high malaria risk zones. The change in ITN ownership explains a drop of 12.1 deaths per 1000 live births out of the overall drop of 20.8, i.e. 58 percent of the overall decline. Unlike the postneonatal results, the infant mortality results imply a mild role for improved sanitation. Increased access to improved sanitation explains 6 percent of the decrease (1.2 deaths per 1000 live births).[10]

Notably, the decomposition point estimate values also imply fairly substantial roles for changes in immunization rates, but the corresponding decomposition results are statistically insignificant. This reflects the fact that although vaccination rates increased substantially, from 53.2 percent to 68.4 percent between the two surveys, the correlation between vaccination and child survival is imprecisely estimated in the cross-sectional regressions. This imprecision may be due to the fact that vaccination rates are measured at the district level and thus only imperfectly indicate the likelihood that a given child was vaccinated.[11]

We interpret these results with caution as evidence of a causal effect of ITNs. However, it is possible that the changes the decomposition attributes to the increase in ITN ownership in high malaria risk zones are actually due to other anti-malarial interventions that are correlated with

[10] In the Oaxaca-Blinder decomposition, the explained part of the overall difference is a sum of positive and negative contributions of all explanatory variables. Thus, the sum of positive contributions alone adds up to more than 100 percent of the overall change.

[11] Vaccination rates are measured this way becase vaccination status is not available for deceased children.

ITN ownership. Indoor residual spraying (IRS) is another effective anti-malarial intervention, which could potentially be more prevalent in households that acquire ITNs. Unfortunately, only the 2008 DHS (and not the 2003 DHS) includes information on IRS, so it is not possible to include IRS in the Oaxaca-Blinder decomposition. However, even in 2008, the rate of IRS remains low: in the sample, just 9 percent of children overall and 11 percent of children in high malaria risk zones lived in households that had received IRS treatment. Additionally, in 2008, the correlation between ITN ownership and IRS was 0.00 overall and -0.03 in high malaria risk zones. The combination of the low prevalence of indoor spraying and lack of correlation with ITN indicate that changes in indoor spraying are unlikely to be driving the results presented here.

Another confounding factor is that between 2003 and 2008 there was an increase in the use of artemisinin combination therapy (ACT) for malaria treatment. In the 2003 DHS, among children who had a fever within the previous two weeks, 11 percent received sulfadoxine-pyrimethamine (SP), the recommended drug treatment at the time. In 2008, among the same category of children, 3 percent received SP and 8 percent received ACT. If ITN usage is correlated with access to ACT treatment, it is possible that part of the decline in mortality attributed to ITN usage is a consequence of increased availability of ACT.

Table 7 also presents results from a similar decomposition for the change in neonatal mortality, which shows a small, statistically insignificant increase. This decomposition is included for the sake of completeness and also as a modest falsification test of the main finding regarding ITN ownership in high malaria-risk zones. Given that malaria and ITN ownership are known not to have a substantial effect on neonatal mortality, we do not expect changes in ITN ownership to explain any part of the change in neonatal mortality. If ITN ownership did explain changes in neonatal mortality, that would suggest that the ITN ownership results for postneonatal mortality were driven by unobserved factors rather than ITN ownership itself. The decomposition for neonatal mortality, however, does not indicate that ITN ownership or any other observed factors can explain the change in neonatal mortality.

The fact that the postneonatal and infant mortality decompositions do not imply statistically significant roles for other candidate factors—including facility births, antenatal care, and access

to safe water and sanitation facilities—suggests that their role in the decline of infant mortality is likely to be small. As noted earlier, although the decomposition implies a large role for the increase in vaccination, there is substantial uncertainty around that estimate. Additionally, the analysis does not capture the possible role of HIV/AIDS. The overall HIV prevalence rate among women age 15-49 declined from 8.7 percent in 2003 to 8.0 percent in 2008 (according to the DHS). The pattern of HIV prevalence by malaria-risk zone does not suggest that the changes in infant mortality are due to the overall drop in HIV infection rate; within high malaria-risk zones, HIV infection rates increased slightly. There were also efforts during this period to increase access to retroviral drugs for pregnant women and those with newborns. Unfortunately, data on access to these drugs is not available.[12]

Another factor which the analysis cannot adequately capture is the role of economic growth. The overall summary figures shown in Table 2 show that while there is no clear pattern of variation of neonatal mortality by wealth quintile, postneonatal mortality is generally lower in wealthier quintiles. This pattern for postneonatal mortality, however, does not hold in the regressions shown in Table 4. Controlling for observed characteristics, the wealthiest three quintiles have slightly higher levels of postneonatal mortality. One possible interpretation of these results is that the overall lower postneonatal mortality rates among households in wealthier quintiles are due to the greater access that wealthier households have to factors captured in the analysis—ITN ownership, improved sanitation, improved water source, etc. The wealth index that can be constructed using DHS variables is only suitable for relative comparisons of wealth within a particular survey and is not suitable for analyzing absolute changes in wealth over time. Consequently, we do not include a wealth measure in the decomposition index and cannot make definitive statements about the role of growth in wealth (or economic growth overall) in the decline of infant mortality.

Overall, we take these results as indicative evidence that the increased availability of ITNs in high malaria risk areas of Kenya is a major driver of the substantial decreases in postneonatal and infant mortality observed in Kenya between 2003 and 2008.

[12] For reasons of confidentiality, HIV test results for DHS respondents are not matched to responses to other parts of the survey. Consequently, we cannot include mother's HIV status in the regression analysis.

5 The Cost Effectiveness of Insecticide-Treated Net Allocations in Kenya

On April 25, 2000, heads of African countries met in The African Summit on Roll Back Malaria and signed the Abuja declaration with the aim of reducing malaria mortality by one half by 2010. One of the three main measures, that was agreed on, was the expansion of ITN usage by population at risk—particularly pregnant women and children under 5 years—to 60 percent by 2005 (Abuja Declaration 2000). In order to increase the availability and usage of ITNs in Kenya, the already existing retail sale of ITNs at full cost was complemented by social marketing campaigns selling ITNs at a subsidized price, by routine distribution through antenatal and child health clinics, and by free mass distribution campaigns (Kenya Malaria Indicator Survey 2010).[13] Most of these programs have been funded by international development initiatives. Their cost effectiveness might be highly policy-relevant, particularly for decision making on funding of further ITN keep-up campaigns.

The overall costs of ITN delivery programs in Kenya are not known. As for costs per ITN delivered, the experience shows that the costs vary greatly among the different delivery channels, with the amount of subsidy per ITN, between the type of bednet, and over time. In the light of the existing literature on the costs and cost effectiveness of various ITN delivery initiatives in Sub-Saharan Africa, we estimate the cost per ITN delivered to be US$ 5.[14] The benefit of interest in this case is the number of infant deaths averted by the increases in ITN ownership. If we take a

[13] Social marketing campaigns on ITNs have been conducted by Population Services International Kenya (PSI/Kenya) since 2002. The main focus of the campaigns has been to increase the awareness of ITNs' contribution to avoiding malaria and to deliver partially subsidized ITNs through the commercial sector (National Social Marketing Centre 2010). Distribution of heavily subsidized ITNs and long-lasting insecticide-treated bednets (LLIN) through Maternal and Child Health clinics by PSI/Kenya and Ministry of Health followed in 2004 and 2005 (Noor et al 2007). In 2006, 3.4 million LLINs were distributed for free to children under 5 years in two massive campaigns in districts of Kenya that are affected by malaria (Hightower 2010). The first distribution (1.4 million LLINs) was integrated with measles vaccination campaign; the second campaign (2 million LLINs) was conducted separately. Over time, there was a shift towards distribution of LLINs. Unlike traditional ITNs, LLINs do not need to be retreated with insecticides every 6 to 12 months. Furthermore, LLINs provide more "treated net years" than ITNs which leads to protection at lower annual costs in spite of LLINs' higher provision costs (Yukich et al 2008).

[14] The estimated cost of US$ 5 represents an average cost per ITN delivered in Kenya over a five year period 2003-2008. For further details on its assessment and for an overview of literature on costs of various ITN delivery initiatives in Sub-Saharan Africa see Annex.

causal interpretation of the Oaxaca-Blinder decomposition estimates, the increase in ITN ownership in high malaria risk zones (HMRZ) of Kenya between 2003 and 2008 decreased infant mortality by 12 deaths per 1000 live births. An estimated 136 live births per 1000 households took place in Kenya during a one year period preceding the DHS 2008. Consequently, the Oaxaca-Blinder estimates imply that 1.64 infant deaths per 1000 households were avoided during that year due to an increased ITN ownership in HMRZ. According to World Malaria Reports (2008, 2010), 15,639,783 ITNs were distributed in Kenya over a five year period mid-2003 through mid-2008. If the annual cost of ITN programs is put into relation to the number of infant lives saved by ITNs per year, the estimated cost per infant life saved is US $1085 is (see Table 8). Similar results were obtained in studies focusing on under 5 mortality, e.g. Yukich et al (2008) estimate costs per death averted at US$ 1174 in Togo, US$ 1222 in Malawi, US$ 1449 in Eritrea, US$ 1745 in Tanzania, and US$ 2926 in Senegal.

These calculations are lower-bound estimates of ITN cost effectiveness, due to the fact that this analysis is restricted to the benefits in terms of lower infant mortality, while ITNs have wider benefits. Most importantly, many child malaria deaths occur after the first year. Additionally, lower transmission rate results in later infections with malaria and “postponed” malaria mortality particularly in intermediate malaria risk zones (Snow and Marsh 2002). Thus, positive effects of ITNs are expected to be larger on under-5 mortality than on infant mortality because the benefits will be found in both HMRZ and IMRZ and a wider age range of children will benefit.

A second reason that the cost effectiveness estimates presented here are lower bounds is that ITNs contribute to lower malaria morbidity and to some extent to lower child comorbidity from other diseases such as diarrhea and tuberculosis (Ashraf et al 2010). Lower morbidity leads generally to less patients and thus lower costs in the health sector. Malaria accounts for 30 percent of outpatient consultations and for 19 percent of inpatient hospital admissions in Kenya (Ministry of Health 2001). In adults, losses in terms of lower productivity and less hours worked are avoided. The Kenyan Ministry of Health (2001) estimates that 170 million working days per year are lost in Kenya due to malaria. For children, lower rates of malaria may increase school attendance and improve cognitive skills are mitigated (Fernando et al 2010).

Comparisons of the 2003 and 2008 DHS data show similar trends in ITN ownership across all malaria risk zones. This indicates that a substantial number of ITNs was acquired in areas of Kenya where malaria is not a major health issue and suggests that better targeting of ITN distribution primarily to malaria-endemic zones could increase the number of lives saved. In its National Malaria Strategy 2009-2017, Kenyan Ministry of Public Health and Sanitation announced a new goal of universal long-lasting insecticide-treated bednets (LLIN) coverage for populations at risk in malaria risk areas by 2013 (Ministry of Public Health and Sanitation 2009). PSI's activities on ITN distribution are still in progress. More recently, USAID promised to contribute 2.7 million ITNs in the campaign against malaria (USAID 2011).

There is some evidence that ITN ownership may have fallen recently. The report from the 2010 Kenya Malaria Indicator Survey (KMIS) finds 47.9 of households owning at least one ITN, compared to 55.7 percent of households in the 2008 DHS, and the KMIS report suggests that this is because a planned distribution to replace aging ITNs did not take place in 2009. The KMIS report also shows an increase in reported malaria rates between 2007 and 2010, although changes in the geographical coverage and age window of the KMIS between the two years makes it difficult to interpret this change, and the data from the survey is not publicly available. In the light of the evidence on the benefits of ITNs' increased availability for infant health in high malaria risk zones of Kenya and given the cost effectiveness of ITN delivery campaigns, continuous interventions and further ITN scale-up and keep-up campaigns are likely be desirable because they are both beneficial to infant health and available at an acceptable cost.

6 Conclusions

Infant mortality has fallen substantially in many countries in Sub-Saharan Africa in recent years. The drop shown for Kenya in the DHS data from 2003 and 2008 is the most rapid in the region for countries for which recent data is available. In this paper, we closely analyze the possible factors for that decline. The Oaxaca-Blinder decomposition analysis implies a substantial role for the increased ownership of insecticide-treated nets, which can account statistically for 58 percent of the overall decline in infant mortality. Our analysis does not find evidence that other

individual factors were substantial contributors to the decline, although the decomposition results imply a small role for improved access to sanitation facilities, are inconclusive as to the effect of increasing immunization, and cannot address the role of increased access drugs to prevent mother-to-child HIV transmission or the overall improvement in economic conditions.

These results should be interpreted with some caution. The Oaxaca-Blinder decomposition approach does not identify causal effects. A causal interpretation of the results relies on the strong assumption that there are no omitted variables, i.e. other factors which determine the outcome and are correlated with the observed explanatory variables. It is likely that this assumption does not hold strictly. Nonetheless, given the wide evidence basis showing that ITN usage can reduce malaria prevalence and the huge surge in ITN ownership in Kenya, it is likely that the decomposition results reflect at least in part a causal effect.

While ITN ownership has increased for all three categories of malaria risk zone, the link between ITN usage and infant mortality is only evident in high malaria risk zones, where less than 40 percent of the Kenyan population lives. ITN ownership may have benefits for intermediate risk areas that are not reflected in this analysis, specifically in reducing child (age 1-5 year) mortality. Additionally, areas which are at intermediate risk today could be at high risk in the future, so wide provision of ITN ownership in intermediate risk areas may be cost-effective. However, ITN ownership also increased dramatically in zones where malaria risk is low, rising from 5 to 47 percent between 2003 and 2008. Given that these ITNs were largely provided on a free or subsidized basis, the cost efficiency of future net distribution campaigns could be improved by focusing campaigns on areas with intermediate and high malaria risk. Noor et al (2010) come to similar conclusions in their analysis of the mismatch of treated net coverage and malaria risk.

It is also important to note that much of the overall change in mortality is not explained by the observable factors analyzed in this paper. For postneonatal mortality, which is the focus of the analysis, 48 percent of the observed change is not explained in the Oaxaca-Blinder decomposition. We highlight two sets of factors which may lie behind this unexplained change. First, improvements in the quality of services and interventions included in our analysis are not captured in our data and thus not reflected in the decomposition. Second, the relatively high

economic growth that took place during the last decade may have caused a generalized improvement in economic conditions that improved child survival.

The rapid decline in infant and under-5 mortality that has taken place in recent years in many countries in Sub-Saharan Africa is an important and largely unrecognized trend that merits further analysis to understand its underlying causes. This study presents some modest findings suggesting that it is likely that the rise in usage and ownership of ITNs played a role in the decline in infant mortality in Kenya, which constitutes a small part of the much broader phenomenon of the reduction in under-5 mortality across many countries. The broader story, and in particular the role of economic growth, could be better analyzed in a study similar to this one, but using data across many countries. That analysis remains as a project for future work.

Annex

Data description and imputation procedures – DHS microdata

The data used in the analysis is from the Demographic and Health Surveys (DHS) conducted in Kenya in 2003 and 2008-2009 (hereafter 2008). The DHS surveys collect information from women aged 15-49 years on their full birth histories, children's health status, and household characteristics, among other things. We focus on individual mortality outcomes of children born 12-35 months before the interview. An attempt was made to reach the highest possible precision when restricting the sample. Thus, the sample was created using data on the day of birth and day of interview. For observations with unknown day of birth, data on the month of birth were used. Our full sample comprises 4827 observations. Due to missing values on explanatory variables, a total of 159 observations was excluded from the analysis, yielding the final sample of 4668 observations. The 2295 observations from the DHS 2003 and 2373 observations from the DHS 2008 correspond to actual live births that took place in Kenya in April 2000-August 2002 and November 2005-February 2008, respectively.

Child mortality is measured at individual level by a dummy variable which takes the value 1 if a child died in a given period and value 0 if it did not die. Depending on the type of mortality, the relevant time period changes. Postneonatal mortality covers the time period after 28 days of age (inclusive) and before the age of 12 months (exclusive). Infant mortality takes into account the

period up to 12 months of age (exclusive). Neonatal mortality covers the period from birth to 28 days of age (exclusive). (World Health Organization 2005)

Cumulative measures of neonatal, postneonatal, and infant mortality are calculated as the number of deaths that were observed in the respective time period per 1000 live births. The calculations are based on the actual survival data of the individuals. Neonatal and postneonatal mortality rates for a cohort sum up to the infant mortality rate. These definitions were chosen so as to be compatible with standard measures, such as those used in official Demographic and Health Survey reports. However, the use of the number of live births, rather than the population surviving to 28 days (the beginning of the postneonatal period) as the reference group for postneonatal mortality generates odd properties for the postneonatal mortality measure. (For example, the upper boundary for the postneonatal mortality rate is less than 1.) To examine the sensitivity of the results, the postneonatal analysis was repeated conditional on survival to at least 28 days. These results (not shown) are very similar to those using the unconditional measured used in the paper.

Definitions of explanatory variables used in the analysis

Due to data unavailability on ITN usage for deceased children, we use a dummy variable on ITN ownership by the household at the time of the interview as a proxy of ITN usage by the child.

Vaccination records are not available for deceased children. Thus, we use immunization rate at district level as an approximation of the individual immunization status. The immunization rate is calculated as the fraction of fully immunized children at district level in our full sample (4827 observations). The definition of full immunization was developed by the World Health Organization (WHO) and is applied by the DHS. A child is considered fully immunized if it received a BCG vaccination (against TBC), three doses of the DPT-HepB-Hib (also called Pentavalent), three doses of polio vaccines (excluding polio vaccine given at birth), and a vaccination against measles. All of these vaccinations are recommended to be given before reaching the age of 12 months (KNBS and ICF Macro 2010). For children with "don't know"

values on immunization status for any of the relevant vaccines, we conservatively assumed that the particular vaccine was not given.

A child is categorized as being born in a facility if it was born in a public or private health facility.

The DHS data on antenatal care was collected for the last birth only. For a child who is not the last birth, the value was approximated by its lastborn sibling. In our final sample (4668 observations), there are 1046 children (22.4%) who are not lastborn. We consider three dummy variables of antenatal care. All of them are considered not received if the mother responded "don't know." Protection against neonatal tetanus is achieved if a pregnant woman without any previous tetanus immunization receives at least two shots of tetanus vaccine during her pregnancy. One or zero tetanus shots during the pregnancy might be sufficient if the mother received previous tetanus immunization and depending on the number and timing of the previous tetanus vaccinations (KNBS and ICF Macro 2010). Due to unavailability of the information on previous tetanus immunization in the DHS 2003, we consider a child protected against neonatal tetanus only if its mother received at least two shots of tetanus vaccine during her pregnancy. The dummy variables on intake of any type of anti-malarial drugs during pregnancy and on intake of iron supplement during pregnancy are self-explanatory. Malaria or lack of iron during pregnancy might lead to anemia of both mother and child and to low birth weight, which in turn increases both neonatal and postneonatal mortality (KNBS and ICF Macro 2010, Snow and Marsh 2002).

Information on the source of drinking water and on the type of sanitation facility is represented by a set of three dummy variables thus distinguishing three stages of quality. In both cases, there is an "improved" category. The concept of improved source of drinking water and improved sanitation facility was proposed by the WHO and UNICEF in 2004 and implemented in the DHS 2008. An attempt was made to approximate the "improved" categories in the DHS 2003 data (KNBS and ICF Macro 2010). In order to obtain time-consistent water and sanitation variables, we slightly diverge from the categorization of improved water source and sanitation proposed in the Kenya DHS 2008 report. A total of 112 observations are excluded from the analysis due to a missing value on water and sanitation quality, which is caused by the mother not being a de jure resident of the household.

Categories for the source of drinking water comprise surface water source, unimproved water source other than surface water, and improved water source. Surface water categories include river, stream, pond, lake, and dam. Additional categories canal and irrigation channel were added in 2008. Improved water source is a source of water suitable for drinking (KNBS and ICF Macro 2010). It includes water piped into the dwelling or plot, public tap or standpipe, and rainwater. Additionally, it comprises covered well in the plot and covered public well in 2003 and tube well or borehole and protected well in 2008. Water sources that do not fall into surface or improved water categories are classified as unimproved water source other than surface water. In 2008, these are unprotected well, protected and unprotected spring, tanker truck, cart with small tank, bottled water, and "other" source.[15] In 2003, unimproved water category consists of open well in the plot, open public well, spring, bottled water, and "other" source.

Variables on sanitation facility comprise no sanitation, unimproved sanitation facility, and improved sanitation facility. Improved sanitation facility is defined as a toilet that is used by members of one household only and that separates excreta from human contact (KNBS and ICF Macro 2010). This includes flush toilet and ventilated improved pit (VIP) latrine; both of them not shared with other households.[16] The unimproved sanitation facility comprises flush toilet and VIP latrine both shared with other households, and "other" toilet. Further facilities falling into this category are pit latrine with or without slab, composting toilet, bucket toilet, and hanging toilet in 2008, and traditional pit toilet in 2003.[17]

[15] Although protected spring is generally considered improved water source, DHS 2003 does not distinguish between protected and unprotected springs. In order to have time-consistent water source categories, we categorize both protected and unprotected springs as an unimproved water source in 2008. According to the Kenya DHS report 2008, 8% of households use protected spring and 5.6% use unprotected spring for drinking water (KNBS and ICF Macro 2010).

[16] DHS 2008 defines flush toilets connected to other than piped sewer system, septic tank or pit latrine as unimproved. In 2003, information on where the flush toilet is connected to is not available. In order to have time-consistent sanitation categories, we consider all flush toilets in 2008 improved. Only 1% of households in 2008 has a flush toilet connected to other than piped sewer system, septic tank or pit latrine (KNBS and ICF Macro 2010).

[17] Although pit latrine with slab that is not shared is generally considered improved sanitation facility, DHS 2003 does not distinguish between pit latrines with and without slab. In order to have time-consistent sanitation categories, we categorize all pit latrines as unimproved sanitation in 2008. According to the Kenya DHS report 2008, 7.8% of households use a not shared pit latrine with slab and 37.9% use pit latrine without slab. Information on shared pit latrines with slab was not published (KNBS and ICF Macro 2010).

The remaining control variables include dummy variables on mother's education (no education, primary, secondary, and tertiary education), wealth quintile (calculated by the DHS and included in the dataset), area of residence (rural and urban area), and province (Kenya has 8 provinces).

Data quality considerations

A number of data concerns can arise in child mortality data in the Demographic and Health Surveys. In the case the of Kenya surveys, these are discussed in the 2008 DHS report (Kenya National Bureau of Statistics and ICF Macro 2010). One possible issue is displacement of reported deaths, which occurs when an interviewer misreports a live birth within the last five years to a period outside that window, in order to avoid having to ask the long series of questions corresponding to births in the last five years. The DHS report finds some evidence that this took place in the 2008 DHS, but this does not affect results presented in this paper, which deal only with births in the one year prior to the survey.

Another potential data problem is omission of births of infants who did not survive. When this occurs, it is usually most pronounced for very young deaths, and thus a low proportion of very young deaths is taken as an indicator of such omission. In the 2008 DHS data, for the five years preceding the survey, the proportion of neonatal deaths occurring during the first week of life is high (82 percent) and the same as the proportion recorded in 2003, suggesting that early neonatal underreporting is minimal and unchanged over time. Similarly, for the five years previous to the survey, the proportion of infant deaths that occurred during the first month of life was high (61 percent), suggesting that underreporting of neonatal deaths was not a serious problem. This was a substantial increase from the 2003 and 1998, for which the corresponding proportions were 47 percent and 41 percent respectively. This increase is the consequence of the large decline in the number of postneonatal deaths (which is the core topic of this paper) rather than a change in the misreporting of neonatal deaths.

An additional possible issue is heaping of reported deaths at 12 months or at 1 month. The data does exhibit a small amount of heaping at age 12 months, but not sufficient to substantially affect the analysis; the deaths reported at age 12 months account for only 6 percent of all infant deaths in the overall sample. Reported deaths by age in death at days do not show any evidence of

heaping at 1 month (Table C.5 of the 2008 DHS report). Nonetheless, to test for sensitivity to misreporting, we also ran the postneonatal analysis using an alternative definition, examining only deaths that took place during at age 2-12 months. These results (not shown) are similar to those for postneonatal mortality presented in the body of the paper.

Data description and imputation procedures – Malaria prevalence data

The data on malaria risk in the DHS clusters were kindly provided by the Malaria Atlas Project funded by the Wellcome Trust, UK. The data stem from a map of infection and malaria risk distribution in Kenya in 2009. The map was created within a Bayesian geostatistical spatial-temporal framework using data on Plasmodium falciparum parasite rates in Kenya in 1975-2009. For further details on methods and data used for the map of malaria risk in Kenya in 2009 see Noor, Gething et al (2009).

Using the GIS information on the location of clusters in Kenya DHS surveys, a malaria risk measure was attributed to each cluster. The measure of malaria endemicity is the posterior predicted mean parasite prevalence (mean PfPR) among children aged 2-10 years. Since the data on malaria prevalence are available for the year 2009, we have a good malaria risk measure for observations from the DHS 2008-2009 and only an approximation for observations in the DHS 2003.[18] The GIS information is missing for one cluster in the DHS 2003 and for one cluster in 2008, leading to the exclusion of the affected observations from the analysis (concerns 20 observations).

Based on a recommendation by Robert Snow from the Malaria Atlas Project, we created a categorical variable on malaria risk. Originally, 5 malaria risk zones were recommended: very low transmission hard to distinguish from zero (mean PfPR lower than 0.1%), low risk (mean PfPR higher than 0.1% and lower than 1%), intermediate low risk (mean PfPR between 1 and 4.9%), intermediate risk (mean PfPR between 5 and 39%), and high risk (mean PfPR higher than 40%). Intermediate risk of malaria is present particularly in the coastal region whereas high risk of malaria is characteristic for lakeside communities at the Lake Victoria. These two categories

[18] There is evidence that malaria prevalence is in transition in Kenya. Particularly, a decrease in the malaria risk was denoted on Kenyan coast (Okiro 2007). Thus, the measure might underestimate malaria risk on the coast in 2003. For other regions, time-trends in malaria are not so clear.

were united into high malaria risk zone (mean PfPR higher than 5%); the first and the second category were united into low malaria risk zone (mean PfPR lower than 1%); the third group is the intermediate malaria risk zone. In the final classification, there are three categories with similar observation shares in each category.

Analysis remark

All the analysis was conducted under consideration of the sampling design of the DHS survey, particularly of the weighting and clustering. However, an alteration was made to the stratum variable in the DHS 2003. Overall, there are 190 strata and 400 clusters in the DHS 2003. This design leads to strata with single cluster in our sample and makes it impossible to calculate standard errors. The DHS 2008 has 15 strata, defined as rural and urban provinces, and 398 clusters. We replaced strata in the DHS 2003 by the stratus definition from the DHS 2008 in order to be able to calculate the standard errors.

Assessment of costs per ITN

The following strategies for delivery of ITNs have been in operation in Kenya since 2002: retail sale of ITNs at full cost, social marketing campaigns selling ITNs at a subsidized price, routine distribution through antenatal and child health clinics, and free mass distribution campaigns (Division of Malaria Control 2010). The overall costs of ITN delivery programs in Kenya are, to our best knowledge, not known. As for costs per ITN delivered, the experience shows that the costs vary greatly among the different delivery channels, with the amount of subsidy per ITN, between the type of bednet (traditional ITN or LLIN), and over time. Social marketing campaigns can be more costly than distributions through antenatal clinics (De Allegri 2009) or through commercial sector (Sexton 2011). Mass distribution campaigns deliver at a lower cost if integrated with other campaigns, e.g. with measles vaccination campaigns. In terms of types of bednets, there was a shift towards distribution of LLINs over time. Unlike traditional ITNs, LLINs do not need to be retreated with insecticides every 6 to 12 months. Furthermore, LLINs provide more “treated net years” than ITNs which leads to protection at lower annual costs in spite of LLINs’ higher provision costs (Yukich et al 2008). Over time, ITN delivery initiatives

lead to lower costs and prices of bednets due to an increasing demand and competition in the ITN and LLIN market.

As shown in Table A1, estimated costs per ITN vary significantly not only by country and by factors mentioned above. They vary as well depending on the methodology that is used for calculation of average unit costs, particularly on the type of costs considered. As a result, there are different estimates of cost per ITN delivered within the same campaign.

Guyatt and Snow (2002) report costs per bednet and insecticide to be around US$ 4.50 – US$ 6 when bought in a bulk. Retail prices of ITNs were US$ 3 – US$ 4 in Tanzania in 2004 (Magesa et al 2005). In 2008, a price for a LLIN was US$ 4.09 – US$ 5.78 in Kenya (Ministry of Health 2009b). WHO estimates an annual cost of protection with LLIN to amount between US$ 1.48 and US$ 2.64 and to average at US$ 2.08 (WHO 2007). Assuming a three year product life, the cost per delivered LLIN can be estimated between US$ 4.44 and US$ 7.92, averaging at 6.24 US$.

Given these estimates and taking into account the fact that there was a gradual shift from distribution of ITNs (lower provision costs) to LLINs (higher provision costs), we consider US$ 5 a reasonable estimate for the average cost per ITN delivered in Kenya over a five year period 2003-2008.

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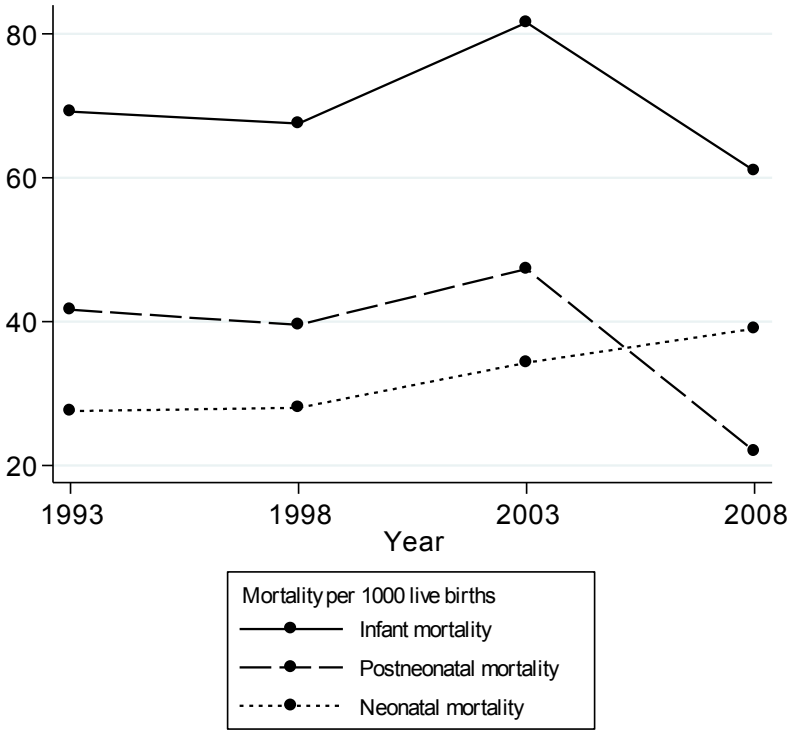
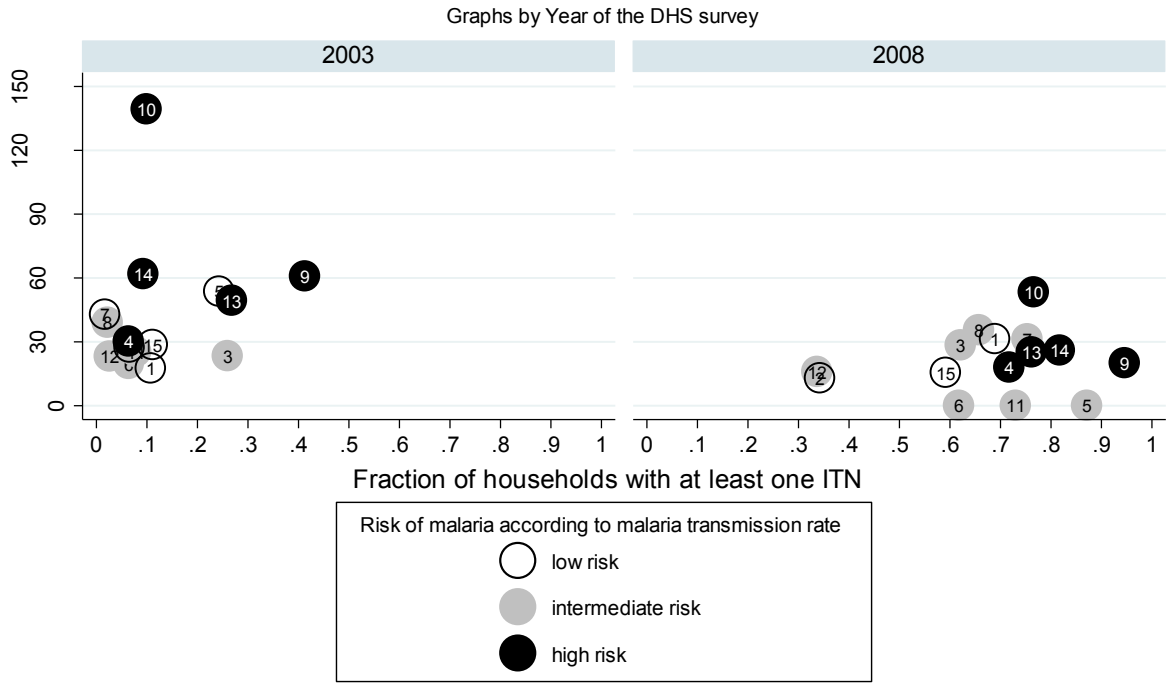
Tables and Figures

Figure 1: Infant Mortality Trends in Kenya



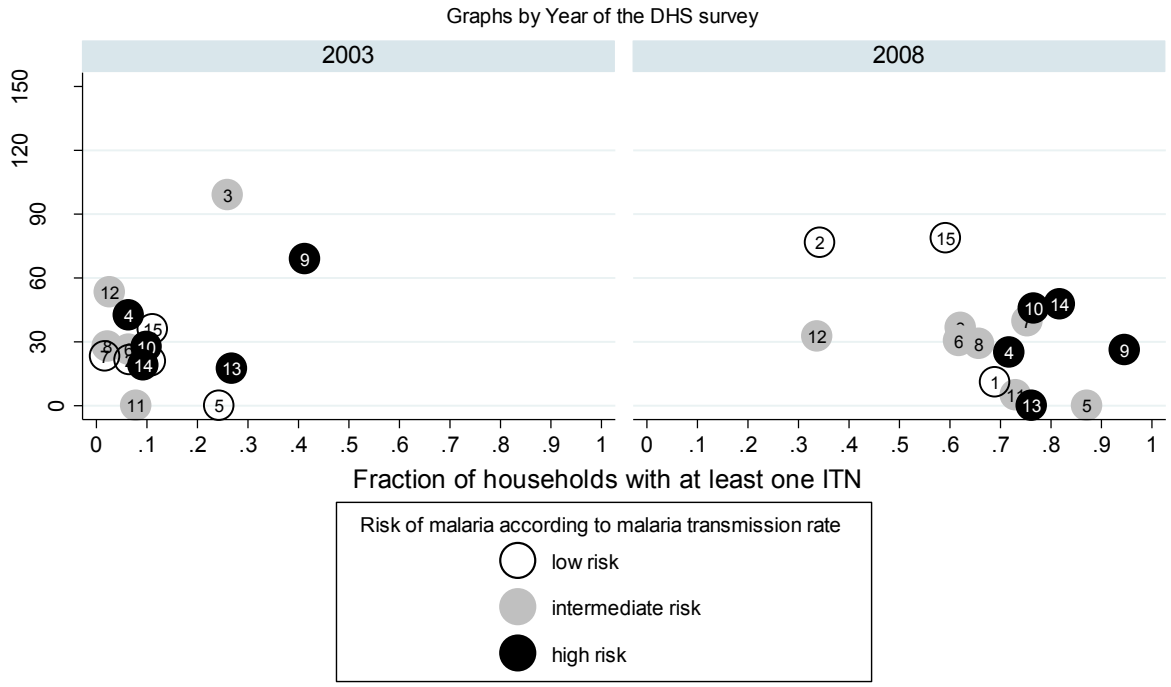
Source: Authors‘ calculations using Demographic and Health Surveys microdata.
Notes: Figures shown are deaths per 1000 live births. Infant mortality refers to deaths before the age of 12 months. Neonatal mortality refers to deaths before the age of 28 days. Postneonatal mortality refers to deaths at the age of 28 days or later and before reaching 12 months. Neonatal and postneonatal mortality rates sum to the infant mortality rate. These figures are calculated using the actual live births that took place during the period 12-35 months before the survey date.

Figure 2: Postneonatal Mortality vs. Insecticide-Treated Net Ownership by Province and Urban/Rural Location by Year and Average Malaria Prevalence



Source: Authors' calculations using Demographic and Health Surveys microdata.
Notes: Trends in the number of children who died at the age of 1 month or later and before reaching 12 months. Measured per 1000 live births. Legend: 1 Central province urban, 2 Central province rural, 3 Coast province urban, 4 Coast province rural, 5 Eastern province urban, 6 Eastern province rural, 7 Northeastern province urban, 8 Northeastern province rural, 9 Nyanza province urban, 10 Nyanza province rural, 11 Rift Valley province urban, 12 Rift Valley province rural, 13 Western province urban, 14 Western province rural, 15 Nairobi province. These figures are calculated using the actual live births that took place during the period 12-35 months before the survey date.

Figure 3: Neonatal Mortality vs. Insecticide-Treated Net Ownership by Province and Urban/Rural Location by Year and Average Malaria Prevalence



Source: Authors' calculations using Demographic and Health Surveys microdata.
Notes: Trends in the number of children who died before the age of 1 month. Measured per 1000 live births. For legend, see Figure 7. These figures are calculated using the actual live births that took place during the period 12-35 months before the survey date.

Table 1: Infant and under-5 mortality trends in Sub-Saharan African countries with a Demographic and Health Survey since 2005

Country	DHS survey	Infant mortality rate		Under-5 mortality rate	
		per 1000 live births	% decline per year	per 1000 live births	% decline per year
Benin	2001	89		160	
	2006	67	5.5%	125	4.8%
Ethiopia	2005	77		123	
	2011	59	4.3%	88	5.4%
Ghana	2003	64		111	
	2008	50	4.8%	80	6.3%
Guinea	1999	98		177	
	2005	91	1.2%	163	1.4%
Kenya	2003	77		115	
	2008	52	7.6%	74	8.4%
Lesotho	2004	91		113	
	2009	91	0.0%	117	-0.7%
Liberia	2007	71		110	
	2009	73	-1.4%	114	-1.8%
Madagascar	2003	58		94	
	2008	48	3.7%	72	5.2%
Malawi	2004	76		133	
	2010	66	2.3%	112	2.8%
Mali	2001	113		229	
	2006	96	3.2%	191	3.6%
Mozambique	2003	101		152	
	2011	64	5.5%	97	5.5%
Namibia	2000	38		62	
	2006	46	-3.2%	69	-1.8%
Niger	1998	123		274	
	2006	81	5.1%	198	4.0%
Nigeria	2003	100		201	
	2008	75	5.6%	157	4.8%
Rwanda	2007	62		103	
	2010	50	6.9%	76	9.6%
Senegal	2005	61		121	
	2010	47	5.1%	72	9.9%
Tanzania	2004	68		112	
	2010	51	4.7%	81	5.3%
Uganda	2006	71		128	
	2011	54	5.3%	90	6.8%
Zambia	2001	95		168	
	2007	70	5.0%	119	5.6%
Zimbabwe	2005	60		82	
	2010	57	1.0%	84	-0.5%
Average			3.6%		4.2%

Source: Demographic and Health Survey website's STATcompiler tool, supplemented by figures from DHS reports for the most recent surveys, which are not yet accessible via STATcompiler. See References section for details. All figures correspond to the 5-year period prior to the survey. For surveys covering multiple years, the first year is recorded as the survey year.

Table 2: Disaggregated neonatal, postneonatal, and infant mortality

	Mortality (per 1000 live births)					
	Neonatal		Postneonatal		Infant	
Overall	36.3	(3.88)	34.2	(4.02)	70.5	(5.40)
By survey						
2003 survey	34.3	(4.66)	46.6	(6.92)	80.9	(8.23)
2008 survey	38.3	(6.19)	21.9	(4.01)	60.2	(7.08)
By malaria risk zone and ITN ownership						
Low malaria risk zone (LMRZ)	36.3	(6.90)	16.1	(3.46)	52.4	(7.49)
Intermediate malaria risk zone (IMRZ)	36.6	(6.84)	19.9	(4.40)	56.5	(9.37)
High malaria risk zone (HMRZ)	36.1	(6.34)	62.2	(9.52)	98.3	(10.40)
ITN ownership	37.3	(8.07)	24.1	(4.40)	61.4	(8.59)
No ITN ownership	35.9	(4.19)	39.5	(5.66)	75.3	(6.88)
ITN ownership in LMRZ (1)	48.8	(19.32)	14.2	(5.90)	63.0	(19.73)
No ITN ownership in LMRZ (1)	32.0	(6.43)	16.8	(4.18)	48.7	(7.51)
ITN ownership in IMRZ (1)	28.7	(12.22)	15.5	(6.64)	44.2	(13.81)
No ITN ownership in IMRZ (1)	40.2	(8.57)	21.8	(5.66)	62.0	(12.40)
ITN ownership in HMRZ (1)	34.8	(10.94)	34.2	(7.76)	68.9	(11.75)
No ITN ownership in HMRZ (1)	37.2	(7.22)	85.2	(15.33)	122.3	(15.18)
By antenatal and natal care						
Born in a facility	52.9	(7.79)	24.0	(4.10)	76.9	(8.57)
Not born in a facility	25.2	(4.25)	41.0	(5.76)	66.3	(6.79)
Antenatal tetanus protection	37.8	(5.56)	34.3	(4.54)	72.1	(6.90)
No antenatal tetanus protection	34.7	(5.42)	34.1	(6.01)	68.8	(7.89)
Antenatal antimalarial drugs	31.9	(5.77)	32.2	(5.33)	64.1	(7.43)
No antenatal antimalarial drugs	38.3	(4.97)	35.1	(5.15)	73.4	(6.96)
Antenatal iron supplement	36.2	(5.24)	34.3	(4.82)	70.6	(7.26)
No antenatal iron supplement	36.5	(6.22)	34.0	(5.39)	70.5	(7.87)
By access to drinking water and sanitation						
Surface water	31.9	(5.66)	48.7	(9.10)	80.5	(10.48)
Unimproved water source (not surface)	39.3	(7.76)	25.3	(5.13)	64.6	(9.45)
Improved water source	37.8	(6.83)	29.1	(4.98)	66.9	(8.25)
No sanitation	35.8	(7.95)	50.8	(10.36)	86.6	(12.37)
Unimproved sanitation	37.4	(4.89)	32.0	(4.05)	69.3	(6.23)
Improved sanitation	29.6	(9.74)	13.4	(6.66)	43.0	(11.50)
By mother's education						
No education	31.6	(8.79)	31.3	(6.99)	62.9	(11.40)
Primary education	34.1	(4.59)	42.1	(5.90)	76.3	(7.08)
Secondary education	32.3	(8.09)	14.7	(4.48)	46.9	(9.00)
Tertiary education	101.7	(37.73)	5.0	(3.64)	106.7	(37.78)
By household's poverty status						
1st wealth quintile (poorest)	38.8	(7.91)	36.9	(7.29)	75.8	(10.46)
2nd wealth quintile	28.7	(7.49)	37.6	(7.93)	66.2	(11.82)
3rd wealth quintile	38.9	(8.20)	47.5	(10.32)	86.4	(12.36)
4th wealth quintile	32.0	(8.96)	21.1	(6.07)	53.1	(11.00)
5th wealth quintile (richest)	42.6	(9.66)	25.1	(5.56)	67.6	(11.60)
By urban/rural area and by province						
Urban area	35.7	(9.00)	22.7	(4.65)	58.4	(10.23)
Rural area	36.5	(4.30)	36.9	(4.82)	73.4	(6.19)
Nairobi province	57.0	(23.97)	18.3	(6.41)	75.3	(24.52)
Central province	36.4	(9.83)	23.2	(6.96)	59.6	(12.17)
Coast province	40.8	(10.18)	26.7	(7.52)	67.4	(12.51)
Eastern province	28.5	(9.73)	9.9	(5.05)	38.4	(10.48)
Nyanza province	39.1	(8.69)	85.2	(16.72)	124.3	(17.86)
Rift Valley province	36.4	(7.19)	18.3	(5.26)	54.8	(8.89)
Western province	31.1	(13.27)	43.0	(9.63)	74.0	(14.42)
North Eastern province	27.4	(8.22)	38.1	(12.34)	65.6	(18.38)

See next page for table notes.

Source: Authors‘ calculations using Demographic and Health Surveys microdata.
Notes: Robust standard errors are shown in parentheses. Sample size: 4668 observations.
The sample is restricted to the relevant malaria zone. Corresponding number of observations in the respective samples: 1560 in LMRZ, 1359 in IMRZ, 1737 in HMRZ.

Table 3: Descriptive statistics depicting fraction of observations (children) with following characteristics

	Survey					
	2003		2008		Both	
Household's malaria risk location and ITN ownership						
Low malaria risk zone (LMRZ)	36.9	(2.76)	36.1	(3.74)	36.5	(2.17)
Intermediate malaria risk zone (IMRZ)	28.3	(2.88)	24.4	(3.02)	26.3	(2.04)
High malaria risk zone (HMRZ)	34.8	(2.77)	39.5	(3.54)	37.2	(2.00)
HH owns an ITN and lives in LMRZ	2.0	(0.33)	17.0	(2.09)	9.5	(1.11)
HH does not own an ITN and lives in LMRZ	35.0	(2.70)	19.2	(2.92)	27.0	(1.88)
HH owns an ITN and lives in IMRZ	2.5	(0.47)	13.9	(1.85)	8.2	(0.96)
HH does not own an ITN and lives in IMRZ	25.8	(2.74)	10.5	(1.66)	18.1	(1.64)
HH owns an ITN and lives in HMRZ	3.8	(0.60)	29.5	(2.82)	16.7	(1.56)
HH does not own an ITN and lives in HMRZ	31.0	(2.61)	9.9	(1.46)	20.4	(1.55)
ITN ownership overall	8.3	(0.79)	60.4	(2.47)	34.4	(1.75)
ITN ownership in LMRZ (1)	5.3	(0.87)	47.0	(4.36)	26.0	(2.61)
ITN ownership in IMRZ (1) (2)	9.0	(1.51)	57.2	(3.43)	31.3	(2.84)
ITN ownership in HMRZ (1) (2)	10.6	(1.57)	74.6	(2.50)	44.9	(3.19)
% of children under 1 year sleeping under an ITN (3)	7.2	(0.83)	55.8	(2.36)	30.5	(1.40)
% of pregnant women sleeping under an ITN (4)	5.4	(0.94)	49.0	(3.47)	26.4	(2.04)
Antenatal, natal, and postnatal care						
Child received all vaccinations (5)	53.2	(1.70)	68.4	(1.65)	60.9	(1.25)
Born in a facility	39.6	(1.69)	40.7	(2.04)	40.2	(1.25)
Antenatal tetanus protection	51.6	(1.34)	53.3	(1.62)	52.4	(1.04)
Antenatal antimalarial drugs	20.8	(1.18)	40.2	(1.83)	30.6	(1.21)
Antenatal iron supplement	49.2	(1.59)	67.7	(1.70)	58.5	(1.26)
Household's access to drinking water and sanitation						
Surface water	33.9	(2.40)	28.3	(2.50)	31.1	(1.69)
Unimproved water source (not surface)	28.2	(2.08)	22.9	(1.81)	25.5	(1.36)
Improved water source	37.9	(2.26)	48.8	(2.67)	43.4	(1.73)
No sanitation	22.3	(2.23)	18.8	(2.29)	20.6	(1.54)
Unimproved sanitation	70.9	(2.18)	70.2	(2.32)	70.6	(1.54)
Improved sanitation	6.8	(0.80)	11.0	(1.24)	8.9	(0.74)
Mother's education						
No education	15.5	(1.75)	11.7	(1.72)	13.6	(1.18)
Primary education	63.7	(1.75)	65.1	(1.99)	64.4	(1.29)
Secondary education	16.8	(1.12)	18.7	(1.46)	17.8	(0.90)
Tertiary education	4.0	(0.48)	4.6	(0.75)	4.3	(0.44)
Household's poverty status						
1st wealth quintile (poorest)	24.7	(1.84)	23.8	(2.09)	24.2	(1.34)
2nd wealth quintile	20.8	(1.31)	20.9	(1.51)	20.9	(0.96)
3rd wealth quintile	19.2	(1.14)	19.3	(1.54)	19.2	(0.93)
4th wealth quintile	16.5	(1.37)	16.5	(1.50)	16.5	(1.01)
5th wealth quintile (richest)	18.8	(1.67)	19.5	(2.55)	19.2	(1.38)
Household's location: urban/rural area and province						
Rural area	81.2	(1.59)	81.2	(2.52)	81.2	(1.19)
Nairobi province	6.6	(0.88)	5.2	(1.05)	5.9	(0.54)
Central province	10.3	(1.20)	7.7	(1.22)	9.0	(0.60)
Coast province	8.6	(1.26)	7.8	(1.52)	8.2	(0.77)
Eastern province	15.0	(1.94)	15.1	(2.38)	15.1	(1.18)
Nyanza province	16.5	(2.08)	20.2	(2.44)	18.3	(1.12)
Rift Valley province	27.0	(2.42)	28.3	(3.48)	27.7	(1.58)
Western province	12.7	(1.62)	13.0	(2.54)	12.9	(1.21)
North Eastern province	3.1	(0.65)	2.8	(0.57)	3.0	(0.31)

See next page for table notes.

Source: Authors‘ calculations using Demographic and Health Surveys microdata.
Notes: Robust standard errors are shown in parentheses. Sample size: 4668 observations.
(1) Sample is restricted to the relevant malaria zone.
(2) Observations from strata with single sampling unit were excluded.
(3) Figure based on a different sample – children born up to 12 months before the interview and alive.
(4) Figure based on a different sample – pregnant women in full DHS sample.
(5) Based on children alive only. Vaccination records are not available for deceased children. For definition of "all vaccinations" see Annex.

Table 4: Regression results for postneonatal mortality in 2003 and 2008 in Kenya

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Intermediate malaria risk zone (IMRZ)	0.0038	0.0032	0.0025	0.0008	0.0012	0.0037	-0.0000
High malaria risk zone (HMRZ)	0.0662***	0.0614***	0.0605***	0.0605***	0.0579***	0.0616***	0.0381**
Interaction LMRZ and ITN ownership	0.0080	0.0085	0.0102	0.0108	0.0128	0.0115	0.0122
Interaction IMRZ and ITN ownership	0.0045	0.0043	0.0054	0.0092	0.0099	0.0084	0.0041
Interaction HMRZ and ITN ownership	-0.0386**	-0.0383**	-0.0373**	-0.0349**	-0.0342**	-0.0379**	-0.0424***
2008 survey	-0.0195**	-0.0130	-0.0134	-0.0143	-0.0141	-0.0119	-0.0183*
Full immunization (district level)		-0.0417	-0.0415	-0.0420	-0.0509*	-0.0495	-0.0017
Birth in clinic			-0.0078	-0.0057	-0.0033	-0.0059	-0.0089
Antenatal tetanus protection			0.0070	0.0072	0.0073	0.0069	0.0083
Antenatal antimalarial drugs			-0.0007	-0.0007	-0.0000	-0.0002	0.0012
Antenatal iron supplement			-0.0006	-0.0006	-0.0010	-0.0016	-0.0044
Unimproved water source (not surface)				-0.0257**	-0.0251**	-0.0276***	-0.0310***
Improved water source				-0.0090	-0.0065	-0.0136	-0.0135
Unimproved sanitation				-0.0034	-0.0078	-0.0176	-0.0186
Improved sanitation				-0.0145	-0.0139	-0.0257*	-0.0263*
Mother has primary education					0.0213	0.0193	0.0077
Mother has secondary education					0.0018	-0.0019	-0.0147
Mother has tertiary education					-0.0048	-0.0082	-0.0220
2nd wealth quintile						0.0145	0.0124
3rd wealth quintile						0.0316**	0.0311**
4th wealth quintile						0.0181*	0.0185*
5th wealth quintile (richest)						0.0301**	0.0316**
Rural area							0.0015
Central province							0.0010
Coast province							-0.0061
Eastern province							-0.0128
Nyanza province							0.0553**
Rift Valley province							-0.0075
Western province							0.0149
North Eastern province							0.0165
Constant	0.0237***	0.0473***	0.0475***	0.0612***	0.0538***	0.0483***	0.0381*
Number of observations	4668	4668	4668	4668	4668	4668	4668
R-squared	0.0234	0.0249	0.0255	0.0288	0.0316	0.0344	0.0433
F-statistics	4.4604	4.0084	3.0946	2.4864	2.8731	2.6283	2.2600

Source: Authors‘ calculations using Demographic and Health Surveys microdata.
Notes: Linear probability model, pooled sample. Dependent variable is a dummy variable on child's survival status. It takes value 1 if the child died in postneonatal or infant period. For categorical variables with more than two categories, the left-out categories are: Low malaria risk zone (LMRZ), Surface water, No sanitation, Mother has no education, 1st wealth quintile (poorest), Nairobi province. Full immunization variable measures fraction of children with all vaccinations at district level. Vaccination records are not available for deceased children. For definition of "all vaccinations" see Appendix. Significance levels are marked as follows: * 10%, ** 5%, *** 1%.

Table 5: Regression results for neonatal mortality in 2003 and 2008 in Kenya

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Intermediate malaria risk zone (IMRZ)	0.0086	0.0089	0.0131	0.0120	0.0124	0.0114	0.0081
High malaria risk zone (HMRZ)	0.0058	0.0086	0.0169	0.0156	0.0164	0.0141	0.0093
Interaction LMRZ and ITN ownership	0.0142	0.0139	0.0088	0.0098	0.0072	0.0077	0.0103
Interaction IMRZ and ITN ownership	-0.0143	-0.0141	-0.0179	-0.0175	-0.0160	-0.0160	-0.0154
Interaction HMRZ and ITN ownership	-0.0054	-0.0056	-0.0104	-0.0088	-0.0105	-0.0091	-0.0082
2008 survey	0.0050	0.0011	0.0062	0.0056	0.0066	0.0061	0.0038
Full immunization (district level)		0.0250	0.0197	0.0265	0.0290	0.0273	0.0364
Born in a facility			0.0296***	0.0325***	0.0302***	0.0316***	0.0322***
Antenatal tetanus protection			0.0008	0.0005	0.0008	0.0008	0.0011
Antenatal antimalarial drugs			-0.0099	-0.0097	-0.0103	-0.0110	-0.0097
Antenatal iron supplement			-0.0026	-0.0028	-0.0037	-0.0033	-0.0044
Unimproved water source (not surface)				0.0089	0.0084	0.0099	0.0111
Improved water source				0.0024	0.0004	0.0041	0.0043
Unimproved sanitation				-0.0099	-0.0091	-0.0042	-0.0014
Improved sanitation				-0.0236	-0.0347*	-0.0296	-0.0292
Mother has primary education					-0.0021	-0.0003	0.0010
Mother has secondary education					-0.0078	-0.0053	-0.0042
Mother has tertiary education					0.0669*	0.0704*	0.0704*
2nd wealth quintile						-0.0141	-0.0136
3rd wealth quintile						-0.0036	-0.0017
4th wealth quintile						-0.0168	-0.0126
5th wealth quintile (richest)						-0.0149	-0.0092
Rural area							0.0205*
Central province							-0.0353
Coast province							-0.0124
Eastern province							-0.0343
Nyanza province							-0.0166
Rift Valley province							-0.0206
Western province							-0.0258
North Eastern province							-0.0137
Constant	0.0302***	0.0161	0.0063	0.0078	0.0085	0.0117	0.0088
Number of observations	4668	4668	4668	4668	4668	4668	4668
R-squared	0.0009	0.0014	0.0074	0.0085	0.0138	0.0148	0.0166
F-statistics	0.3099	0.5431	1.6654	1.3013	1.2799	1.1153	0.9228

Source: Authors‘ calculations using Demographic and Health Surveys microdata.
Notes: Linear probability model, pooled sample. Dependent variable is a dummy variable on child's survival status. It takes value 1 if the child died in postneonatal or infant period. For categorical variables with more than two categories, the left-out categories are: Low malaria risk zone (LMRZ), Surface water, No sanitation, Mother has no education, 1st wealth quintile (poorest), Nairobi province. Full immunization variable measures fraction of children

with all vaccinations at district level. Vaccination records are not available for deceased children. For definition of "all vaccinations" see Appendix. Significance levels are marked as follows: * 10%, ** 5%, *** 1%.

Table 6: Regression results for infant mortality in 2003 and 2008 in Kenya

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Intermediate malaria risk zone (IMRZ)	0.0124	0.0121	0.0157	0.0128	0.0136	0.0152	0.0080
High malaria risk zone (HMRZ)	0.0720***	0.0701***	0.0774***	0.0761***	0.0743***	0.0757***	0.0473**
Interaction LMRZ and ITN ownership	0.0222	0.0224	0.0190	0.0207	0.0200	0.0193	0.0225
Interaction IMRZ and ITN ownership	-0.0097	-0.0098	-0.0125	-0.0083	-0.0061	-0.0076	-0.0113
Interaction HMRZ and ITN ownership	-0.0440**	-0.0439**	-0.0477**	-0.0438**	-0.0447**	-0.0470**	-0.0506***
2008 survey	-0.0145	-0.0119	-0.0072	-0.0087	-0.0075	-0.0059	-0.0144
Full immunization (district level)		-0.0167	-0.0218	-0.0155	-0.0219	-0.0222	0.0347
Birth in clinic			0.0218**	0.0268**	0.0269**	0.0258**	0.0233**
Antenatal tetanus protection			0.0078	0.0077	0.0081	0.0077	0.0094
Antenatal antimalarial drugs			-0.0107	-0.0104	-0.0103	-0.0112	-0.0085
Antenatal iron supplement			-0.0033	-0.0035	-0.0047	-0.0049	-0.0087
Unimproved water source (not surface)				-0.0168	-0.0166	-0.0177	-0.0199
Improved water source				-0.0066	-0.0061	-0.0095	-0.0091
Unimproved sanitation				-0.0134	-0.0168	-0.0218	-0.0200
Improved sanitation				-0.0382**	-0.0487**	-0.0553**	-0.0555**
Mother has primary education					0.0193	0.0189	0.0086
Mother has secondary education					-0.0060	-0.0072	-0.0190
Mother has tertiary education					0.0622	0.0623	0.0484
2nd wealth quintile						0.0004	-0.0013
3rd wealth quintile						0.0281*	0.0295*
4th wealth quintile						0.0013	0.0059
5th wealth quintile (richest)						0.0152	0.0224
Rural area							0.0219
Central province							-0.0343
Coast province							-0.0186
Eastern province							-0.0471
Nyanza province							0.0387
Rift Valley province							-0.0281
Western province							-0.0110
North Eastern province							0.0028
Constant	0.0539***	0.0633***	0.0539***	0.0690***	0.0622***	0.0600***	0.0470
Number of observations	4668	4668	4668	4668	4668	4668	4668
R-squared	0.0120	0.0122	0.0143	0.0163	0.0194	0.0211	0.0277
F-statistics	3.6371	3.1176	3.0139	2.6566	2.4190	2.4445	2.2881

Source: Authors‘ calculations using Demographic and Health Surveys microdata.
Notes: Linear probability model, pooled sample. Dependent variable is a dummy variable on child's survival status. It takes value 1 if the child died in postneonatal or infant period. For categorical variables with more than two categories, the left-out categories are: Low malaria risk zone (LMRZ), Surface water, No sanitation, Mother has no

education, 1st wealth quintile (poorest), Nairobi province. Full immunization variable measures fraction of children with all vaccinations at district level. Vaccination records are not available for deceased children. For definition of "all vaccinations" see the Annex. Significance levels are marked as follows: * 10%, ** 5%, *** 1%.

Table 7: Oaxaca-Blinder decomposition of the difference in postneonatal and infant mortality between 2003 and 2008 in Kenya

	Neonatal	Postneonatal	Infant
2003 survey	34.32***	46.62***	80.94***
2008 survey	38.34***	21.85***	60.19***
Difference between 2003 and 2008	-4.02	24.77***	20.75*
Explained part of the difference	2.03	12.82*	14.86*
Unexplained part of the difference	-6.05	11.94	5.89
Low malaria risk zone (LMRZ)	-0.07	-0.17	-0.24
Intermediate malaria risk zone (IMRZ)	0.11	-0.70	-0.58
High malaria risk zone (HMRZ)	-0.26	-1.85	-2.11
Interaction LMRZ and ITN ownership	-1.16	-1.73	-2.89
Interaction IMRZ and ITN ownership	1.83	-0.96	0.87
Interaction HMRZ and ITN ownership	2.34	9.73**	12.07**
Full immunization (district level)	-4.23	7.68	3.44
Born in a facility	-0.35	0.06	-0.28
Antenatal tetanus protection	-0.01	-0.12	-0.13
Antenatal antimalarial drugs	2.13	0.05	2.18
Antenatal iron supplement	0.62	0.29	0.91
Surface water	-0.26	0.76	0.50
Unimproved water source (not surface)	0.28	-0.74	-0.46
Improved water source	0.06	-0.01	0.05
No sanitation	0.39	0.50	0.90
Unimproved sanitation	0.05	-0.02	0.03
Improved sanitation	0.77	0.47	1.24*
Mother has no education	-0.62	-0.09	-0.71
Mother has primary education	0.23	-0.23	-0.01
Mother has secondary education	0.40	0.08	0.48
Mother has tertiary education	-0.33	0.06	-0.27
1st wealth quintile (poorest)	0.09	-0.17	-0.08
2nd wealth quintile	0.01	0.01	0.01
3rd wealth quintile	-0.01	-0.01	-0.02
4th wealth quintile	0.00	0.00	0.00
5th wealth quintile (richest)	0.04	-0.08	-0.04
Number of observations overall	4668	4668	4668
Number of observations in 2003	2295	2295	2295
Number of observations in 2008	2373	2373	2373

Source: Authors‘ calculations using Demographic and Health Surveys microdata.
Notes: Based on regressions in column 6 of Tables 4 and 6. Shown is only decomposition of the explained part of the difference. Contributions of explanatory variables sum up to the explained part of the difference. Significance

levels are marked as follows: * 10%, ** 5%, *** 1%.

Table 8: Cost-Benefit Analysis of ITN Delivery in Kenya between 2003 and 2008

Estimation of infant deaths averted by ITNs	
Live births p.a. per 1000 households	136.23
Infant deaths averted by ITNs per 1000 live births	12.07
Infant deaths averted by ITNs p.a. per 1000 households	1.64
Estimation of costs of ITNs delivery	
Number of ITNs distributed 2003-2008	15,639,783
Number of households	8,767,954
Number of ITNs distributed p.a. per 1000 households	356.75
Cost per ITN in US$	5.00
Costs of ITNs distributed p.a. per 1000 households in US$	1,784
Cost-benefit analysis of ITNs delivery	
Cost per infant death averted by ITNs in US$	1,085

Source: Authors‘ calculations using Demographic and Health Surveys microdata and World Malaria Reports data.
Notes: Estimate of live births is based on the actual live births that took place 1 to 12 months before the Kenya DHS 2008 survey. Infant deaths averted by ITNs are based on the Oaxaca-Blinder decomposition results, see Table 5. Estimate of distributed ITNs is based on the number of ITN and LLIN bednets distributed over a five year period mid-2003 – mid-2008 (World Malaria Report 2008, World Malaria Report 2010). Number of households stems from Kenya Census 2009. The estimated cost of US$ 5 represents average costs per ITN delivered over a five year period 2003-2008. For an overview of literature on costs of various ITN delivery initiatives in Sub-Saharan Africa see Annex.

Table A1: Cost calculations for Recent ITN Delivery Initiatives in Sub-Saharan Africa

Country	Period	Cost per ITN in US$		Delivery channel	Reference
		Financial	Economic		
Kenya	2000	8.42		community based targeted subsidized distribution	Guyatt et al 2002b
Kenya	2000	4.68		community based targeted subsidized distribution	Kolaczinski & Hanson 2006
Kenya	2001	5.26		free distribution through antenatal clinics (ANC)	Guyatt et al 2002a
Ghana	2002	3.74		free mass distribution integrated with measles vaccination	Grabowsky et al 2005a
Zambia	2003	4.67 rural area		free mass distribution integrated with measles vaccination	Grabowsky et al 2005b
Zambia	2003	5.06 urban area		free mass distribution integrated with measles vaccination	Grabowsky et al 2005b
Togo	2004	6.11		free mass distribution integrated with measles vaccination	Yukich et al 2007
Togo	2004	3.23		free mass distribution integrated with measles vaccination	Yukich et al 2008
Togo	2004	5.95		free mass distribution integrated with measles vaccination	Mueller et al 2008
Malawai	1998-2003	2.63		social marketing, targeted distribution through ANC	Stevens et al 2005
Malawi	1998-2005	4.13	3.36	social marketing, targeted distribution through ANC	Yukich et al 2007
Senegal	2000-2005	10.34	8.05	commercial sector, subsidies, voucher scheme	Yukich et al 2007
Eritrea	2001-2005	5.44	4.74	free distribution through ANC, community-level distribution	Yukich et al 2007
Eritrea	2001-2005	4.72	3.98	free distribution through ANC, community-level distribution	Yukich at al 2009
Tanzania	2002-2005	5.3	4.32	social marketing, voucher scheme	Yukich et al 2007
Tanzania	2002-2005	4.8		social marketing, voucher scheme	Yukich et al 2008
Tanzania	2004-2006	7.57		voucher scheme	Mulligan et al 2008
Burkina Faso	2006-2007	8.08	4.81	social marketing	De Allegri et al 2009
Burkina Faso	2006-2008	7.21	4.81	free distribution through ANC	De Allegri et al 2009