Achieving a Better Understanding of The Malaria Control System

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Introduction

According to the latest World Malaria Report (WHO 2008), there were an estimated 247 million malaria cases among 3.3 billion people at risk in 2006, causing nearly a million deaths, mostly of children under 5 years. One hundred nine countries were endemic for malaria in 2008; 45 within the WHO African region. The report raises the concern that, despite big increases in the supply of mosquito nets, especially in Africa, the number of nets available in 2006 was still far below need in almost all countries. The procurement of anti-malarial medicines through public health services also increased sharply, but access to treatment, especially of Artemisinin-based Combination Therapies (ACT), was inadequate in all countries surveyed in 2006.

The burden of disease is not evenly distributed across the countries affected by Malaria. Of the 3.3 billion people at risk worldwide, 2.1 billion are at low risk (i.e., <1 reported case per 1,000 population) with 97% of the low-risk population residing outside of Africa (WHO 2008). Of those at high risk (i.e., ≥1 case per 1,000), 49% live in Africa and 37% live in South-East Asia (WHO 2008). Eighty-six percent of the estimated 247 million Malaria cases in 2006 occurred in Africa, 80% of those cases occurred in 13 countries, and over half occurred in 6 countries (Nigeria, Democratic Republic of the Congo, Ethiopia, Tanzania, and Kenya) (WHO, 2008).

The supply of Insecticide Treated Nets (ITNs) and Long-lasting Insecticide Impregnated Nets (LLINs) has been increasing but coverage is still far from adequate. In 2006, only 6 countries in Africa had enough nets (both ITNs and LLINs) to cover at least 50% of their at risk populations (Ethiopia, Kenya, Madagascar, Niger, Sao Tome and Principe and Zambia). In the 37 African countries that reported coverage data in 2006, there were only enough ITNs to cover 26% of people in need (WHO, 2008). Indoor Residual Spraying (IRS) is another prevention method and is used in every region that grapples with Malaria, but IRS coverage is at 70% of households for only a few countries (WHO, 2008). Treatment of Malaria through Artemisinin-based combination therapy (ACT) increased sharply from 6 million in 2005 to 49 million in 2006 (estimates). Forty-five million of the treated cases were in Africa (WHO, 2008).

Funding for Malaria control has been increasing and, in 2006, it was greater than ever. However, for most countries it is still not possible to assess the impact of funding on the availability of resources and the reductions in morbidity and mortality. The World Malaria Report 2008 argues that the estimated $4.60 per Malaria case that is available is not likely to suffice to meet preventive and curative goals. Yet a handful of countries reduced the prevalence of Malaria by 50% or more between 2000 and 2007. These countries, Eritrea, Rwanda, Sao Tome and Principe, and Tanzania, are relatively small, have high coverage rates and good surveillance systems. This enables them to demonstrate the link between funding, coverage and prevalence. In other countries, such as Ethiopia, Kenya and Niger, where large proportions of the populations also have access to prevention and treatment, no such links can be shown due to either poor surveillance or ineffective interventions (WHO, 2008). In general, WHO maintains that
the links between interventions and trends remain ambiguous and recommends more careful investigation into the effects of interventions to control Malaria.

Objective and Research Questions

The present study addresses the ambiguity of trends highlighted in the World Malaria Report by attempting to disentangle the relationship between Malaria trends, funding, and interventions. We posit that the existing global Malaria control system is suffering from a poor level of efficiency and that it reacts to trends post-hoc in three separate steps. We employ a conceptual model that includes three sequential causality paths that flow in a closed-loop fashion to simulate a Malaria control system. The process begins with the reaction of governments and donors to a significant rise in the Malaria cases. We expect that the level of funding increases as Malaria cases increase. Next, we expect that the increase in funding leads to an increase in delivery of prevention and treatment services. Finally, an increase in utilization of services is expected to reduce Malaria cases and mortality. These three key steps to global Malaria control are examined over a 6-year time period (2001 through 2006) using econometric techniques designed for panel data. The paths are depicted graphically in Figure 4 on page 8. In addition, our study revealed a phenomenon whereby the Malaria prevalence rates diverged significantly from the mean for two clusters of countries. This important finding is discussed as well.

Overview of Findings and Their Implications

There are several major findings that have policy and research implications. A complete summary is found at the end of this analysis. We briefly list the main findings and implications here:

Trends in Funding

- Over the last four years, funding for Malaria has increased. Donor funding has increased more sharply than government funding.
- Countries with less effective governments rely more upon donor funding.

Relationship between cases and funding

- There is a positive relationship between the level of funding for Malaria and the number of Malaria cases.
- Generally, Malaria interventions are funded in response to disease trends. Donors are more reactive in their funding than governments. Government funding is steadier.
- There is an additive effect for funding from the previous year to the current year.

Relationship between funding and coverage
• While increase in funding expands the coverage for almost all interventions, the effect size, measured in terms of elasticity, is not big enough which indicates low efficiency of funds.
• Once the funding is available the expansion of coverage does not take place rapidly rather its effect is partially delayed by as long as one year. Particularly for countries that rely heavily on donor funds, interventions are often too little too late.

Relationship between coverage and cases

• While the coverage has been increasing globally a cluster of countries with higher number of Malaria cases have not succeeded to bring the trend under control.
• The behavior of control systems has been fundamentally different: the countries with high number of cases relied on distributed mosquito nets, spraying services, and drugs in combating Malaria (mostly from donors and in vertical manner), whereas the low case countries have taken advantage of their own health systems’ efforts (horizontal programs).

Divergence

• Two clusters of countries diverge from the mean. A cluster with a low number of cases did an acceptable job controlling Malaria. A cluster with a high number of cases has been experiencing an increase in disease prevalence over time.
• Eight of the 10 countries with the highest prevalence rates are receiving less than their share of interventions based on their level of disease burden. This is contributing to the divergence phenomenon.
• In the high prevalence cluster, 61.1% perform poorly. In the low prevalence cluster, 14.7% perform poorly.
• Twenty-six percent of countries are following a deteriorating trend.
• Countries with low prevalence can reduce their number of cases through their health systems. Countries with high prevalence require vertical programs to deliver interventions.

Implications

• A new funding strategy is needed to address critical issues of efficiency and timing. Instead of continuing with the current model of post-hoc funding, strategies should be revised to promote sustainable budgets for programs with long time horizons. This would take advantage of economies of scale and learning by doing and would greatly reduce the lag time between outbreaks and delivery of interventions.
• Approaches to the delivery of services should be structured based on the capabilities of health systems in countries. Countries with weaker systems need vertical programs to deliver care.
• A set of 10 countries with high prevalence have not been able to control Malaria, thus prevalence is getting worse. Eight of the 10 countries receive less than their
share of interventions and this contributes to their deteriorating trend. These countries need vigorous and targeted help to turn this trend around.

Following this section, we describe the trends of funding and coverage. Next, a conceptual framework developed to represent the Malaria control process is explained using a path diagram. Then a section on data and variables provides detailed information about the availability, quality, and decisions around the use of the data in this study. The section that follows explains the three econometric models. Next, the results and findings from the three paths are presented followed by an analysis of the divergence phenomenon that emerged from this study. Following the analysis of divergence is a series of scenarios simulating possible future trends in Malaria. Finally, there is a discussion summarizing the major results and their implications for policy and research. We suggest next steps for conducting more investigations to document the best practices followed in countries that have reduced their number of Malaria cases and their potential value for countries still experiencing an increase in their Malaria cases.

**Trends of Funding and Coverage**

This section uses trend data to provide an overview of the changes that have occurred during the six-year period under study. We present graphs depicting the trend in vector control and treatment modalities, the trend in global funding for Malaria both by modality and by source of funding, and the trend of reported cases.

Between 2001 to 2006, there has been a steady growth in coverage for Malaria through the use of ITN/LLIN, IRS, and treatments including ACT. Coverage of household spraying has remained low and steady. Figure 1 depicts the trend of vector control and treatment modalities during the 2001-2006 period. The data for year 2007 are not shown due to incomplete data for all countries.
Figure 1: Trends of Coverage for Malaria

The variables used to create Figure 1 are:

- Total number of ITN + LLIN sold or delivered (60 countries more than zero; 215 country-year more than zero)
- Total number of households sprayed (61 countries more than zero; 236 country-year more than zero)
- Total number of people protected by IRS (43 countries more than zero; 168 country-year more than zero)
- Total number of any first-line treatment courses delivered (including ACT) (73 countries more than zero; 278 country-year more than zero)

In Figure 2, the trend of spending reported by donors, countries, The President’s Malaria Initiative (PMI), and the Global Fund (GFATM) in million US dollars is shown. Individual countries have consistently spent the most on controlling Malaria (almost $1.2 billion). Donors spent almost $800 million in 2006 and The Global Fund committed about $400 million that year.

Figure 2: Trend of funding from different sources for Malaria
Figure 3 depicts the trend of the malaria reported cases for the period of 2001-2006. For comparability, 89 countries that have reported the cases for all years are graphed in Figure 3. In spite of the reasonable increase in funding followed by coverage modalities (Figures 1 and 2), over the 6 years of study period, the reported cases of Malaria have not shown a significant decline. The number of Malaria cases steadily increased until 2005 with the trend showing a decline for 2006. As we will discuss later, based on our regression analyses, two clusters of countries are recognizable: a group of countries with lower cases have done an acceptable job, yet the group of high case countries experienced an increase in disease over time. Malaria cases in sum show an increasing trend (Figure 3) due to the dominance of high case countries in terms of the number of cases in each year. This divergence from the mean has divided the countries into two clusters: the group that most probably will move toward controlling and even eradication, and the group that faces even bigger challenges in future.
Figure 3: Trends of reported cases (89 countries with data for all years of 2001-2006 period)

![Trends of Reported Malaria Cases (in Million, 2001-2006)](image)

Source: Authors based on WHO Malaria Report (WHO 2008)

The statistics on cases are based on the country reports, however the estimated cases calculated by WHO for year 2006 suggest significant under-reporting for almost all countries with large discrepancies among high prevalence countries like Nigeria, Democratic Republic of the Congo, Ethiopia, and India. According to WHO, there were an estimated 247 million malaria cases among 3.3 billion people at risk in 2006. Of those, only 94 million were reported by countries (in Figure 3 for 89 countries graphed based on the country reports, 87 million cases is shown in 2006).

**Conceptual Framework of the Closed-loop Path of Financing-Service Provision-Health Outcome for Malaria Control System**

We hypothesize that the Malaria control system acts in three separable steps in a post-hoc manner. It begins with the reaction of governments and donors to a significant rise in Malaria cases whereby the level of funding responds to the feedback from Malaria outcomes. The first reaction in our model will be an increase in funds by donors and governments to be spent on prevention and treatment modalities. The next step is the expansion of prevention and treatment services to increases in funds. We call the provision of these services ‘intermediate outcomes.’ The utilization of services by at-risk populations eventually leads to controlling the cases which is the final outcome.
These three steps construct a closed loop with feedback from final outcomes (Malaria cases) to initial inputs (funds). Of course each of these steps might happen with a delay. If all steps act efficiently and in a timely manner, then our hypothetical system should control the prevalence of Malaria over a reasonable time with a reasonable amount of funds.

A path diagram of these cyclical causal relationships that construct a feedback-looped structure is illustrated in Figure 4. The relation between the outcome and funds and between funds and prevention and treatment services are hypothetically direct (positive). The negative relation between prevention and treatment services and outcomes should theoretically bring the Malaria outcomes under control as illustrated in this model.

Figure 4: Path Diagram of “Financing-Service Provision-Health Outcome” for Malaria Control System

In order to simulate this system, we use econometric modeling techniques. The econometric models are designed to examine three causality paths separately.
Data and Variables

In this section, we describe the variables, datasets used, some of the limitations of the data, and where necessary, the rationale for including the chosen data. We had to gather data on the three factors investigated. However, the control variables included in the analysis had to be limited by the availability or likely significance to measuring the causality paths. While the variables left out make the models incomplete, we believe the major findings will hold with a more complete set of control variables.

Our analysis uses the following secondary datasets:

- First dataset reports the statistics on both vector controls and treatment for Malaria for the period of 2001-2007 (109 countries have 757 country-year observations)
- The second dataset includes the donor and country reported spending for Malaria for the period of 2001-2007 (87 countries have 407 country-year observations).
- The third dataset provides us with the key outcome data in terms of reported Malaria cases for period of 2001-2007 (93 countries have 445 country-year observations for Malaria cases).

Country-Sample

The Merged file of Coverage-Funding has 502 country/year records. Ninety-four countries are represented for at most 7 years (2001-2007). The number of countries in each WHO Region are as follows: Africa=39; Americas=19; Eastern Mediterranean=9; Europe=8; South-East Asia=10; Western Pacific=9. However, the real sample size shrinks to a lower number due to missing data and to the use of lagged variables rather than immediate ones where needed. The sample size also shrinks depending on which set of dependent and independent variables will be used in various regression analyses.

Vector control and treatment modalities for Malaria

The effect of three vector control modalities and one treatment modality on the number of Malaria cases is examined. Vector control aims to decrease contacts between humans and vectors of human disease. Control of mosquitoes may prevent malaria as well as several other mosquito-borne diseases. The three modalities of vector control studied in this analysis are: Insecticide-Treated Bed Nets (ITNs), Long-Lasting Insecticide-treated Nets (LLINs), and Indoor Residual Spraying (IRS). The effect of Artemisinin-based combination therapies (ACTs) as a treatment modality is also studied. Information about each of these interventions is available in the Annex.
We included control variables of government effectiveness and rainfall as well as a dummy variable for each year to account for changes occurring over time.

Government Effectiveness

A dataset of country typology provided by Ranson et al. (2003) was used to account for constraints to scaling-up interventions (84 low-income and all sub-Saharan African countries). Ranson et al. (2003) found substantial heterogeneity across the 84 low-income and (all) sub-Saharan African countries analyzed. Poor sub-Saharan African countries are the most highly constrained; Asian countries, in general, less constrained; and the two Asian giants, China and India, consistently fall above the median. Former Soviet Union countries rank low in terms of governance, but high for health systems variables. Some of the major indicators determining level of constraint in Ranson et al. study were the following: GDP per capita for financial constraint, women literacy for community/household level, nurses per population, vaccination coverage, and access to health services for health system delivery, control of corruption and government effectiveness as environmental characteristics.1

The absorptive capacity measured by level of constraint, is arguably a factor in the effectiveness of funding across countries. We have adopted the ranking provided by Ranson et al. (2003) for 84 studied countries in order to control for constraints affecting the causality relations in Malaria control system.

Although a country’s absorptive capacity can restrict the expansion of the intervention and new technologies for vector control and treatment, government effectiveness can be used to examine the relation between interventions and disease prevalence. The “government effectiveness indicator” at the country-year level was used because this indicator can and should theoretically impact the efficiency but also the socio-demographic and risk-based targeting of the procured interventions better than other policy indicators. The data on the government effectiveness was provided by The Worldwide Governance Indicators (WGI) project (World Bank Group 2009).

Climate and Rainfall

Climate is believed to play a complex role in the transmission and prevalence of Malaria by affecting the vector (population of mosquitoes) and the variation in malaria prevalence both between countries and within countries over time. Rainfall, temperature and humidity are the variables most often used to study the influence of climate on Malaria prevalence (Briet, et al., 2008). In this study, we control for the influence of climate on prevalence using a Rainfall variable even though the rainfall data available through

1 Another framework of the constraints to improving access to health care was considered for use in this study. Hanson et al (2003) captures two additional levels of constraints (i.e., health sector policy and cross-sectoral policy). Ideally, the effects of constraints at these levels should also be measured, but this proves too difficult why?. We provide more details about the Hanson et al. and the Ranson et al. frameworks in the Annex.
different sources are far from perfect predictors of prevalence. As one expert in the field suggests, a certain combination of the temperature and a very critical interval of rainfall that is timely and also remains volume-wise within a specific range, among other conditions, is required to provide the suitable environment for a mosquito outbreak. Reiter (1988) has also discussed the limitations of using the annual aggregate rainfall data as the predictors of the disease prevalence. Considering the more sophisticated datasets on climate conditions is however beyond the scope of this project. The climate factor in particular has to be taken into account in analysis of the third path where we study the effectiveness of interventions procured to control the prevalence of the disease. The country-year rainfall measures therefore are controlled for in the intervention/outcome model.

Because annual rainfall data are not readily available in a universal and comparable manner for all countries, we constructed such a dataset in two steps. First, we extracted the satellite rainfall measures reported in equal intervals in terms of longitude and latitude for different zones of the earth. In the second step, we found the satellite reading points that are within the rectangular approximation of each country using the borderline longitude and latitude of each country provided by the maps of the world in the www.world.com website.

**Econometric Models**

As we mentioned earlier, all datasets include variables for countries over a number of years. Such datasets are known as Panel-Data and the most common modeling technique for such datasets are Fixed/Random-Effect models. In Random-Effect modeling techniques, both time-variant variables (e.g. funding) and time-invariant variables (e.g. constraint) can enter the model simultaneously. While the level of constraint of each country does vary over time, in our analysis, it is treated as a constant because the constraint measure is not available for the different years between 2001-2007.

Although Random-Effect models always provide more efficient estimates over Fixed-Effect models, the consistency of the estimates ought to be examined using statistical tests such as Hausman test. The test will be performed for all models. When the Random-Effect models provide inconsistent estimates, modifications in the explanatory variables or use of the Fixed-Effect estimates will be considered.

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2 Personal interview with Eric J. Olson, Ph.D., biologist and faculty at Brandeis University.

3 Reiter (1988) using empirical data discusses such limitation: “The St. Louis data clearly illustrates the limitations of summarizing weather data in seasonal or monthly terms, and this applies equally to other times of the year. Arthropods can exploit warm periods in an otherwise "cold" spring. High total rainfall may suggest a wet summer but be too intermittent to provide suitable groundwater breeding sites. A brief killing frost can obviate the effects of a warm autumn”.

4 The rainfall data are gathered from monthly precipitation by merging gauge readings with 5 kinds of satellite estimates (GPI, OPI, SSM/I scattering, SSM/I emission and MSU) and numerical model predictions (mm/day). The data for all countries of the world from 2001-2007 were provided through the CPC Merged Analysis of Precipitation Version 0809, through the Climate Prediction Centre.
In trend graphs provided earlier, we used the aggregate data for each year. Since we had a smaller number of countries in year 2007, we limited the graphic illustrations to the period of 2001-2006. Our panel-data models, however, are not constructed based on aggregate data, rather they are quite flexible to accept any number of countries with valid data in each year. In these regression models, both between country variations and country specific over-time variations are taken into account for estimation of coefficients. Therefore, it is quite legitimate to keep as many observation-years as we can.

We begin with the lower left path of our path diagram. A Random-Effect model explaining the effect of health outcomes as of reported cases of Malaria in interaction with government effectiveness of each country, on the level of funding by government and donor community is provided in Model 1 below.

**Model 1**

\[
\text{Log(Funds)}_{it} = b_0 + b_1 \text{Government Effectiveness}_{it} \\
+ b_2 \text{Log(Malaria Cases)}_{it} + b_3 \text{Gov. Eff.} _{it} * \text{Log(Malaria Cases)}_{it} \\
+ b_4 \text{Log(Malaria Cases Prev. Year)}_{it} + b_5 \text{Gov. Eff.} _{it} * \text{Log(Malaria Cases Prev. Year)}_{it} \\
+ b_6 \text{Year2003}_{it} + \ldots + b_{10} \text{Year2007}_{it} + U_{it}
\]

Connotation of each time-variant variable indicates the association of each observation with country \(i\) in year \(t\). In this model noted, the dependent variable is the logarithm of Funding for each country \(i\) in year \(t\). Since both Malaria Cases and Funding variables have skewed distributions log transformations were used.

As shown in the above model, the level of funding is not expected to change immediately in response to observed Malaria cases. The term “cases of previous year” is entered to the model to capture the potential lag effect. In Model 1, as well as the next paths’ models, the selection between immediate and the lagged effects (or if necessary combination of both), will be made based on the standard errors of the coefficients’ estimates.

While some of the interventions are paid for through private contribution in the form of out of pocket payments by households, data currently available lack such information particularly in high prevalence and poor countries. The models’ estimates therefore are explaining the behavior of the funds allocated and reported by two major sources; the government spending and donor funds.

The next path (upper path in diagram) is assessed by Model 2. The model explains the effect of funding in interaction with level of constraint of each country on the coverage variables.

**Model 2**

\[
\text{Log(Preventive/Treatment Coverage)}_{it} = b_0 + b_1 \text{Constrained}_{i} \\
+ b_2 \text{Log(Fund)}_{it} + b_3 \text{Constrained}_{i} * \text{Log(Fund)}_{it}
\]
Connotation of each time-variant variable indicates the association of each observation with country \( i \) in year \( t \) whereas for time-invariant variable of Level of Constraint the single index of \( i \) indicates a steady level of constraint over time for country \( i \). The Constraint independent variable was treated as a dummy variable to indicate whether the country was highly constrained (1) or less constrained (0), where highly constrained were those countries that fell into quartiles 1 and 2 in the Hanson et al (2003) ranking.

This Random-Effect construct is able to explain the effect of Funding during both the current and previous year for each individual country in each year in interaction with the Level of Constraint for each specific country on the Level of Coverage in each specific country for each year.

The final Random-Effect model examines the effectiveness of prevention and treatment modalities (lower right path). This path is the most important path in our diagram. The estimates of this model are controlled for exogenous climate effects proxied by the annual rainfall data. The model also examines the role of the government in increasing the efficiency of the interventions using the government effectiveness indicators at the country-year level. The strength of health system is also considered as one of the major contributors in combating Malaria. By separating the sample into the high- and low-Malaria case countries and proper use of interaction terms, the model investigates the differential impacts of major independent variables in two clusters of countries.

Model 3:

\[
\text{Log(Malaria Cases)}_{it} = b_0 + b_1(\text{Coverage})_{it} + b_2(\text{Coverage} \ast \text{HighCaseCountry})_{it} + b_3(\text{Government Effectiveness})_{it} + b_4(\text{Government Effectiveness} \ast \text{Coverage})_{it} + b_5(\text{RainFall})_{it} + b_6(\text{RainFall} \ast \text{HighCaseCountry})_{it} + b_7(\text{Health System Indicator})_{it} + b_8(\text{Year2002})_{it} + \ldots + b_{13}(\text{Year2007})_{it} + b_{14}(\text{Year2002} \ast \text{HighCaseCountry})_{it} + \ldots + b_{19}(\text{Year2007} \ast \text{HighCaseCountry})_{it} + U_{it}
\]

Results and Findings

All three paths will be modeled for the time period of 2001-2007. The study time period of the post MDG declaration is advantageous because during the first half of the MDG life span, the behavior of the key stakeholders are investigated in terms of their commitment to increasing funds and resources as well as their efforts to improve the efficiency of their investments to combat the disease and attain the MDG Malaria targets.

Prevalence-Funding path

Estimates of Model 1 indicate a positive relation between observed outcome and the level of funds spent on Malaria. When total funds examined for the time period of 2001-2007,
93 countries were represented: 38 from Africa, 10 from South-East Asia, 9 from Western Pacific, 19 from Americas, 9 from Eastern Mediterranean, and 8 from Europe, based on WHO definition of regions (445 country-year observations).

Table 1: Estimates of Model 1 for effect of Malaria cases on total, government, and donor funding.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total Funds (n1,2=93,445)*</th>
<th>External Funds (n1,2=85,352)*</th>
<th>Government Funds (n1,2=61,213)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>10.74 &lt;.001</td>
<td>7.23 &lt;.001</td>
<td>12.70 &lt;.001</td>
</tr>
<tr>
<td>Log(Malaria Cases)</td>
<td>0.27 &lt;.001</td>
<td>0.45 &lt;.001</td>
<td>0.12 0.143</td>
</tr>
<tr>
<td>Government Effectiveness</td>
<td>-0.63 0.360</td>
<td>-1.42 0.064</td>
<td>0.54 0.527</td>
</tr>
<tr>
<td>Log(Malaria Cases) * Gov. Effective.</td>
<td>0.06 0.314</td>
<td>0.10 0.156</td>
<td>0.03 0.741</td>
</tr>
<tr>
<td>Year 2003</td>
<td>0.19 0.295</td>
<td>0.38 0.096</td>
<td>-0.25 0.158</td>
</tr>
<tr>
<td>Year 2004</td>
<td>1.12 &lt;.001</td>
<td>1.49 &lt;.001</td>
<td>0.23 0.178</td>
</tr>
<tr>
<td>Year 2005</td>
<td>1.57 &lt;.001</td>
<td>1.98 &lt;.001</td>
<td>0.30 0.073</td>
</tr>
<tr>
<td>Year 2006</td>
<td>1.88 &lt;.001</td>
<td>2.28 &lt;.001</td>
<td>0.47 0.006</td>
</tr>
<tr>
<td>Year 2007</td>
<td>1.84 &lt;.001</td>
<td>2.19 &lt;.001</td>
<td>1.28 &lt;.001</td>
</tr>
</tbody>
</table>

Dependent variable: Log(Total Funds), Log(External Funds), and Log(Government Funds)
* Indices of n1,2 depict number of observations in terms of 1) country and 2) country-year

The model was separately tried for total funds and its two major components: the government funds and donor funds. The reason for decomposing total funds is to observe potential differences in sensitivity of domestic funds and donor funds reacting to variation of Malaria cases. All funding data come from government reported statistics with some adjustment for cases that the donors have reported their own contributions. Since some items such as technical support and vertical programs contributions can be made in an off-budget manner, an adjustment was made such that, when donor reported funds were higher than the government reported funds, the donor reports were chosen. The upward adjustments were made for The World Bank, Global Fund and the PMI funds. As the WHO report technical notes mention, the monetary values were already converted and reported in constant dollars.

As Table 1 shows, Malaria case counts (in logs) are positively correlated with funding (in logs). However, it appears that external funds by donors are more sensitive to variation of Malaria cases. The sensitivity of government spending to fluctuations of Malaria cases was not significant, indicating a steadier and less susceptible trend for government commitments. All models are controlled for the government effectiveness and its interaction with fluctuation in cases. The estimate of -1.42 for the government effectiveness measure in the donor fund model (weakly significant with p-value =0.06) indicates that the countries with less effective government relied more upon funds from external sources.
The estimate for total and donor funds are 0.27 and 0.45 respectively (p-value<0.001). Since the model is Log-Log, the estimate can be interpreted as **Malaria cases elasticity of funding**. The Malaria cases elasticity of total funds of 0.27 suggests that, by increasing the Malaria cases by 1%, total Malaria funds will increase by 0.27%. The same increase however can stimulate external funds by 0.45%. While the reaction to the fluctuations in cases is lower for government funds, the average level of the government funds available for Malaria is much bigger as the estimates of intercepts of the two models suggest: 12.7 for government funds versus 7.23 for external funds both in logarithmic scale.

Another important finding of Model 1 is the trend of funding over time, shown by the year dummy variables. The positive and significant estimates for dummy variables of at least last 4 years of the study period indicate an increasing trend for total as well as external funds. The rate of growth is much bigger and always highly significant for external funds as compared to less and more often non-significant time trend for government funds. The year dummy variable estimate for year 2007 equal to 1.84 in Logarithmic scale (p-value <0.001) means a huge increase (exp(1.84) = 6.3 times more), compared to base year 2001, in total money spent on Malaria. Level of spending by donors showed a sharper increase over time as for year 2007 it increased as much as 8.9 times (exp(2.19)). While the model estimates for time trends indicate the significant increase in funds for Malaria consistent with recommendation of MDGs, the next paths of our dynamic model should examine the effectiveness of the funds in combating Malaria particularly in high Malaria case countries.

**Limitation**

We mentioned that the data on funding reported by the WHO or other sources do not clearly reflect the private contribution towards prevention/treatment of malaria. In most of the low income countries, the private contribution share of total health expenditure is quite high. The private share in total expenditure of malaria is no exception. Given the high proportion of the private contribution, it is possible that the model estimates of unmet need for funds made by donors and governments have been partially compensated through out of pocket payments. More comprehensive data such as national health accounts with sub classification of major diseases are needed to decompose the financial contribution and reaction of different payers when the outbreak of disease takes place.

**Funding-Coverage path**

There are many modalities of prevention and treatment. However, in Model 2 we will be focusing on the prevention modality of ITN+LLIN and its response to additional funding. The net based vector control is by far the most important prevention strategy as emphasized by the WHO. Its data availability is also better than other interventions at the country-year level.

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5 The term elasticity is used in our analysis to reflect the percentage change in a dependent variable in reaction to percentage change in an independent variable. This interpretation is not at all related to the common application of term i.e. income or price elasticity.
Model 2 was estimated for 57 countries with 177 country-year observations to assess the relation between the available funds and procurement of nets. Table 2, shows the countries from each region (WHO classification was used) with valid (non-missing) data. In the last column, countries from each region are listed with the constrained countries in bold font. Twenty-six out of 57 countries were classified as highly constrained.

Table 2: 57 countries used in regression analysis of effect of funding on # of ITN + LLIN sold or delivered (highly constrained countries in bold font).

<table>
<thead>
<tr>
<th>WHO Region</th>
<th># of countries</th>
<th># of constrained</th>
<th>Country Names</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>29</td>
<td>17</td>
<td>Angola, Botswana, Burundi, Cameroon, Chad, Comoros, Côte d'Ivoire, Democratic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Republic of the Congo, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kenya, Madagascar, Malawi, Mali, Mozambique, Namibia, Nigeria, Rwanda,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Senegal, Sierra Leone, Swaziland, Togo, United Republic of Tanzania, Zambia,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Zimbabwe</td>
</tr>
<tr>
<td>Americas</td>
<td>6</td>
<td>0</td>
<td>Bolivia, Colombia, Ecuador, Honduras, Nicaragua, Suriname</td>
</tr>
<tr>
<td>Eastern Mediterranean</td>
<td>7</td>
<td>4</td>
<td>Iran, Iraq, Pakistan, Saudi Arabia, Somalia, Sudan, Yemen</td>
</tr>
<tr>
<td>Europe</td>
<td>1</td>
<td>0</td>
<td>Tajikistan</td>
</tr>
<tr>
<td>South-East Asia</td>
<td>6</td>
<td>4</td>
<td>Bangladesh, Democratic People's Republic of Korea, India, Indonesia, Myanmar</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nepal</td>
</tr>
<tr>
<td>Western Pacific</td>
<td>8</td>
<td>1</td>
<td>Cambodia, China, Lao People's Democratic Republic, Papua New Guinea, Philippines, Solomon Islands, Vanuatu, Viet Nam</td>
</tr>
</tbody>
</table>

Table 3 shows the estimates of Model 2. The total funds spent in the same year (0.22, p-value=0.020) and previous year (0.19, p-value=0.027) can jointly increase the procurement of the nets.

Table 3: Estimates of Model 2 for effect of country reported funding (same and previous year) and level of constraint on coverage in terms of # of ITN and LLIN sold or delivered.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>4.92</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Constrained Country</td>
<td>0.51</td>
<td>0.138</td>
</tr>
<tr>
<td>Logarithm of Total Funds</td>
<td>0.22</td>
<td>0.020</td>
</tr>
<tr>
<td>Logarithm of Previous Year Total Funds</td>
<td>0.19</td>
<td>0.027</td>
</tr>
<tr>
<td>Year 2003</td>
<td>-0.04</td>
<td>0.903</td>
</tr>
<tr>
<td>Year 2004</td>
<td>0.02</td>
<td>0.956</td>
</tr>
<tr>
<td>Year 2005</td>
<td>0.62</td>
<td>&lt;.045</td>
</tr>
<tr>
<td>Year 2006</td>
<td>0.83</td>
<td>&lt;.010</td>
</tr>
<tr>
<td>Year 2007</td>
<td>1.02</td>
<td>&lt;.014</td>
</tr>
</tbody>
</table>

Dependent variable: Log(ITN + LLIN sold or delivered); n1,2=57countries,177 country-year
The model was repeated for effect of the external money on procurement of nets in order to assess the behavior of the donor allocated money on procurement of nets (not reported). While the previous year donor spending can significantly increase the procurement of the nets (0.06, p-value=0.03) the same year funds do not show any significant effect (p-value=0.1).

The significant delay in procurement is consistent with the argument made by Hanson et al (2003) regarding the limited absorption capacity of the recipient countries. Only 17 out of 57 countries studied in the model are classified as less constrained group according to classification conducted by Ranson et al (2003). According to these studies the limited absorption capacity not only restricts the efficiency of the external funds but also imposes significant delay into procurement and delivery processes. The dynamic nature of Malaria suggests that timely access to preventive interventions such as nets is crucial in bringing periodic outbreaks under control. The estimates of the external fund based model do not support the idea of rapid intervention, however.

In the initial model where total funds determine the procurement of the nets, the estimates were suggestive of an additive effect from the funds made available in the previous and the same year. The additive effect of the two estimates can determine what we call as steady state spending elasticity of coverage. According to our estimates, when the total malaria funds are increased by 1% and the increase is sustained for two consecutive years, the procurement will increase by 0.22% from the same year funds plus 0.19% from the delayed previous year funds. The steady state spending elasticity of coverage is therefore 0.41 which is still far below the unitary elasticity indicating the low efficiency and delayed effect of funds.

The other finding of Model 2 is the trend of coverage over time, measured by the year dummy variables. The positive and significant estimates for trend variables of year 2005 onward indicate an increasing trend of coverage in most recent years. The dependent variable is in Logarithmic scale, therefore for year 2007 (1.02, p-value =0.01) the increase in nets is as big as 2.8 times compared to the base year of 2001.

Coverage –Outcome path

This last path is by far the most important path as far as the efficiency of donor supports and government spending are concerned. This path investigates the effectiveness of services provided in bringing under control the Malaria cases. In Model 3 the dependent variable of is the logarithm of number of Malaria Cases reported for each country-year.

Services are provided in different modalities which are not addable by nature. We bundled up prevention modalities including ITN + LLIN, IRS, and Spraying, and the treatment modality defined as “Any First Line Treatment Including ACT” using Factor Analysis technique and used it as the main independent variable in Model 3. We called the emerged factor ‘Prevention/Treatment Coverage Factor’. The factor analysis technique suggested the following weights for four components: 0.79 for ITN+LLIN,
0.66 for Any 1st Line Treatment Including ACT, 0.51 for IRS and 0.47 for Spraying\textsuperscript{6}. The model was run based on 384 country-year observations from 84 countries.

According to our path diagram the coverage factor made of different modalities supposedly decreases the Malaria Cases. In other words, negative and significant estimates are expected for the coverage factor after controlling for confounding factors in Model 3. The model incorporates a few independent factors that affect Malaria. In order to control for the climate effects on disease, the model uses the country-year measure of rainfall as independent variable. The model also takes into account the variations in government effectiveness. The strength of health system is another factor that model controls for. The health system strength can be proxied by delivery system indicators such as doctors or beds per thousands population or public investments on health by governments. Due to availability and reliability of data, public per capita expenditure in health was preferred to proxy the strength of health system in each country-year.

The initial Model 3 estimates did not show any significant relation between the coverage factors and the number of Malaria cases. Neither the coverage factor nor the health system indicators are able to explain the fluctuations in Malaria universally across the board for all countries. This finding was unexpected; and therefore prompted subsequent analyses that revealed two clusters of countries. We observed that a group of countries that had a lower number of Malaria cases have been able to decrease the number of cases between 2001-2007. However, there is also a group of countries with a high level of cases that experienced an increase in the prevalence of Malaria over the same time period. Based on this observation, we revised Model 3 to investigate the two clusters. We divided the 78 countries included in Model 3 into two subgroups; high (n=41) and low Malaria cases (n=37) countries. To determine whether a country was in the high case cluster, we used the estimated Malaria cases reported by WHO for the 2006, which is reportedly less prone to underreporting. The median point of the cases that divided the 2006’s WHO roster of countries into high and low cases group was 200,000 cases.

Table 4 shows the estimates of Model 3 where two clusters of the high- and low-cases countries are indentified using dummy variables and interaction terms. The coverage factor is not an important contributor in controlling Malaria in low case countries. On the other hand, the coverage factor significantly decreased Malaria in the high case countries (estimate equal to -0.55, p-value=0.017). It should be noted that distributed/sold ITN+LLIN were the most important modalities in calculating the coverage factor.

\textsuperscript{6} We examined ITN+LLIN earlier in Funding-Coverage path. The result of Factor Analysis gives the highest weight to ITN+LLIN among the four major modalities, reaffirming the appropriateness of ITN+LLIN compared to other modalities.
Table 4: Estimates of Model 3 for effect of coverage, government effectiveness, health system strength, and rainfall on Malaria cases as outcome variable.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Est.</th>
<th>p-value</th>
<th>Trend</th>
<th>Variables</th>
<th>Est.</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>10.24</td>
<td>&lt;.001</td>
<td></td>
<td>Low Malaria Cases Cluster</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coverage Factor</td>
<td>-0.37</td>
<td>0.576</td>
<td></td>
<td>Year 2003</td>
<td>-0.27</td>
<td>0.072</td>
</tr>
<tr>
<td>Cvg Fac * High Case Country (HCC)</td>
<td>-0.55</td>
<td>0.017</td>
<td></td>
<td>Year 2004</td>
<td>-0.42</td>
<td>0.003</td>
</tr>
<tr>
<td>Government Effectiveness</td>
<td>-0.42</td>
<td>0.146</td>
<td></td>
<td>Year 2005</td>
<td>-0.50</td>
<td>0.001</td>
</tr>
<tr>
<td>Coverage Factor * Gov. Eff.</td>
<td>0.42</td>
<td>0.120</td>
<td></td>
<td>Year 2006</td>
<td>-0.81</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Log Rainfall</td>
<td>-0.49</td>
<td>0.047</td>
<td></td>
<td>High Malaria Cases Cluster</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log Rainfall * HCC</td>
<td>1.04</td>
<td>0.003</td>
<td></td>
<td>Year 2003</td>
<td>0.60</td>
<td>0.008</td>
</tr>
<tr>
<td>Public Per Cap Health Expenditurea</td>
<td>-0.002</td>
<td>0.062</td>
<td></td>
<td>Year 2004</td>
<td>0.74</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Public Per Cap Health Exp * HCC</td>
<td>0.004</td>
<td>0.263</td>
<td></td>
<td>Year 2005</td>
<td>0.72</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Year 2006</td>
<td>1.11</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Dependent variable: Log(Reported Cases); n1,2 = 78 countries, 299 country-year
a: Public expenditure per capita in health for each country-year in terms of 2005 international dollar prices reported by the World Bank indicators in 2009

The second important observation is that the strength of the health system, proxied by the public expenditures, has a different effect than the coverage factor. In countries with low cases of Malaria, the health system reduces the number of Malaria cases (-0.002, p-value=0.06). The effect is not quite significant but it is important to note. The health system effect does not hold true for countries in the high cases cluster.

These two observations together suggest that an important difference exists between high and low case countries. In countries with a high level of Malaria cases, the interventions that are more vertical, such as distribution of nets, spraying houses and anti malaria drugs, appear to decrease the number of Malaria cases. While in countries with a lower level of cases, horizontal efforts that rely on the health system infrastructure are able to bring Malaria under control.

Rainfall also appears to impact high and low case countries differently. The estimates of rainfall for the high case cluster suggests that the amount of rainfall significantly increases the number of disease cases (1.04, p-value=0.003). The effect of rainfall on Malaria is not clear for the low case cluster; the coefficient estimate is negative (-0.49, p-value=0.047). Given the comparable amount of the rainfall in two groups of countries, there likely exists unobserved factors that mediate the causal relation of climate and the disease prevalence in low the case cluster that do not function similarly in the high case countries.

While the variables included in the revised model explain some of the variations in the Malaria cases, the significance of the trend (year) dummy; positive and significant for the high Malaria country cluster and negative (almost all significant) for the low case countries; means that important additional variables are needed to fully explain the determinants of divergence observed. While we have included structural variables in the model, the additional factors also should evaluate how countries have operationalized their programs to reduce the prevalence of Malaria.
Exploring such factors through additional research, both quantitative and case studies, might indentify best practices among those countries that have reduced the number of malaria cases. Furthermore, the studies could consider under what conditions the dissemination of these practices to high Malaria case countries is possible. To conduct further studies, it would be important to identify countries according to high and low numbers of cases and whether these countries have experienced a decreasing or increasing trend in the number of Malaria cases.

**Divergence in Malaria: High and Low Prevalence and Trends in the Prevalence**

Throughout this analysis, the “number of Malaria cases” has been used as the measure to describe the level of disease in each country. In this ‘Divergence’ section only, we identify countries according to “prevalence” and trend performance. In order to classify the countries into low and high prevalence, the prevalence measure is calculated by dividing the WHO estimated cases by the country’s population (in thousands) both in 2006. The median point of prevalence, equal to 10 per 1000 cases, divides the roster of countries into two high- and low-prevalence groups.

In order to classify countries by their trend performance in combating malaria, we use the reported cases by countries (since the WHO estimate is only available for 2006) to calculate the prevalence for each country for 2001-2006. The World Bank’s World Development Indicators was used for population of each country-year. The prevalence by year for each country was regressed against the year to indicate the trend and the significance of trend. In classifying the countries based on their performance, 108 countries listed in WHO that had reported cases during the period 2001-2006 were used. Of the 108 countries, 10 countries that did not report cases for more than one year and 6 countries with very low cases were excluded. For each of the remaining countries, the regression of prevalence over time was examined. Based on the sign, size and significance of the slope of the trend line, countries were classified according to whether they were experiencing an increase or decrease in prevalence over the 2001-2006 period. This led to dropping 22 countries that had an unclear trend. The remaining 70 countries were divided into two groups: 43 that had a decreasing trend in prevalence (i.e., good) and 27 that had an increasing trend (i.e., poor).

These 70 countries were cross-tabulated based on the two criteria of prevalence (high and low) and trend performance (good and poor). This approach will once again facilitate the test of the hypothesis of divergence from the mean. Table 5 shows the result of cross-tabulation with trend performance in rows and prevalence in columns. Within the high prevalence group, the proportion of poor trend performance countries is 61.1% compared to 14.7% for poor trend performance among low prevalence countries. In the group of countries with low prevalence, 85.3% had a good performance record. The cross tabulation differences are highly significant (p-value<0.001), reaffirming the divergence in trend from the mean that was observed with the dummy variables in Model 3.
Table 5: Tabulation of countries based on the prevalence and performance measures

<table>
<thead>
<tr>
<th>Performance</th>
<th>Prevalence</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>14 (38.9%)</td>
<td>29 (85.3%)</td>
<td>43 (61.4%)</td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>22 (61.1%)</td>
<td>5 (14.7%)</td>
<td>27 (38.6%)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>36 (100%)</td>
<td>34 (100%)</td>
<td>70 (100%)</td>
<td></td>
</tr>
</tbody>
</table>

a: The Fisher exact test indicated the significant difference in proportions; p-value= 0.000

When the 22 countries with mixed-neutral performance and 10 countries with missing reported cases (all excluded from cross-tab in Table 5) are included, we find that over the post-MDG period 26.5% of the countries have been experiencing a rising trend in the number of Malaria cases. More importantly, if these countries have the highest number of malaria cases, then they can impact the world trend. Therefore, analyzing the distribution of Malaria cases among countries is necessary in order to understand the global trend in Malaria cases.

In order to have a measure of the distribution of Malaria, the countries from WHO estimated cases table for 2006 are selected. In addition, to round up the number of countries to 100, four countries: French Guiana, Oman, Egypt, and Jamaica were added.

Figure 5 depicts the cumulative distribution, also known as Lorenz curve (red curve), along with the equal share line (green) for the 100 countries. The curvature of the red curve depicts the unequal manner in which Malaria cases are distributed across countries. Two points on the curve are highlighted; one indicates that 90 of countries count for only 36% of total cases while the other point shows that only five countries account for about 47% of the world’s Malaria cases.
Due to the extremely unequal burden of Malaria and the fact that the countries with high prevalence are much more likely to have experienced an increase in the number of cases, we can predict how the global trend can be negatively affected by the poor trend of a few countries.

**Three Scenarios of Malaria trends for the future**

In this section, we create scenarios of the possible future trends of the 10 countries with the highest number of Malaria cases in an effort to understand how, if at all, the goals of combating Malaria are attainable. The baseline values of Malaria cases are obtained from WHO 2006 estimates. The total number of cases is estimated at about 247 million in 2006 and we simulate the trends through 2020.

The 10 countries with the highest number of Malaria cases are studied separately from the other countries in order to project the trend. The top-10 group with the highest number of cases include: Nigeria (57.5 million cases), Democratic Republic of the Congo (23.6), Ethiopia (12.4), Tanzania (11.5), Kenya (11.3), India (10.7), Uganda (10.6), Mozambique (7.4), Ghana (7), and Côte d'Ivoire (7). Among the remaining ninety countries, seventy one countries that did not have missing years in reporting cases have had in the aggregate a decreasing trend in Malaria cases. The countries with missing data in some years were all among the countries with low number of cases and hence we assumed the decreasing trend of the 71 countries for the missing countries.
So far, we have ninety countries with a general decreasing trend that enable us to do extrapolation over the period of 2006-2020. The extrapolated trend for ninety countries remains unchanged throughout our three simulation scenarios. The future of the top-10 countries, therefore, determines the global trend of Malaria in the simulations.

Scenario 1: Top-10 Countries Stop Experiencing an Increase in the Number of Malaria Cases

In the first scenario, it is assumed that the top-10 high case countries would somehow immediately stop their growing trends in the number of cases. The ninety other countries maintain their trend through the period of simulation. The pooled effect of all 100 countries will lead to a trend shown in blue curve of Figure 6. As the cumulative curve (see Figure 5) has already shown, the ninety countries account only for 36% of the global burden of Malaria. A decreasing trend of the ninety countries therefore will have a weight of 0.36 in changing the global burden of Malaria and would yield a modest downward trend. As a result, the total number of cases in 2020 would still be about 185 million.

The non-growing trend assumed in scenario 1 for the top-10 group does not seem a remote possibility given the fact that, for the latest two years of the study period (2005-2006), the growth rate has been quite low.

Scenario 2: Top-10 Countries Follow the Trend of Those Countries Reducing Malaria Cases

The second scenario assumes that the top-ten countries, under a vigorous set of interventions, would be able to catch up with other countries and join them in combating Malaria. Under this scenario, the average trend of all 100 countries would be equal to the observed trend of the ninety countries. In 2020, under the second scenario, the total number of Malaria cases in the world will decrease to a level as low as 70 million cases.

Scenario 3: Post-MDG Average Performance Trends Are Maintained

We already mentioned that the non-growing situation for the top-10 group seems possible according to their latest years’ (2005-2006) performance. However, over the study period of 2001-2006, the overall number of Malaria cases in the top-10 countries has been seriously increasing. Scenario 3 assumes that the post-MDG average trend for the top-10 countries will be sustained in the future and that no significant intervention would be planned to control it. If this were to occur, the total Malaria cases globally would rise to over 430 million in 2020. This exploding trend is shown in red in Figure 6.
Figure 6: Results of simulation of Malaria trends for period of 2006-2020

Unmet need in high case countries

The second scenario might seem unrealistic at first. However, some countries have proven that this is not an impossibility. Achieving a result like scenario 2 will take much more donor assistance and an expansion in the number of effective interventions. In general, the high Malaria case areas are far more aid dependent than the low prevalence areas. Using the World Bank indicator of aid as a percentage of GNI for period of 2001-2006, the high-case countries had a percentage as large as 14.7% compared to low-case countries, with aid as a percentage of the GNI equal to 3.6% (p-value<0.001). Together, the high aid dependency ratio in high case countries and the effectiveness of vertical interventions in the high-case group indicates that the attainment of the second scenario requires a collaborative effort, by governments and international community in a well targeted and prioritized manner, with special focus on the highest Malaria prone countries.

The disproportionate distribution of interventions for Malaria between countries is one of the factors contributing to the divergence from the mean in Malaria trends. An uneven distribution is leading to unmet need in some areas. WHO acknowledges in its report that, in general, there is a large shortage of nets and anti-Malaria drugs globally. This issue is made worse by the fact that the scarce resources seem to be distributed disproportionally.

In order to examine the extent of inequality in distribution of interventions, we bundled up all interventions using the weights recommended by Factor Analysis similar to what was done in the Path 3 model. The weights for four components are: 0.79 for ITN+LLIN, 0.66 for Any 1st Line Treatment Including ACT, 0.51 for IRS and 0.47 for Spraying. We calculated the share of each country from total interventions for Malaria and compared it
against the share of each country of global malaria burden as estimated by WHO for 2006.

A fair share ideally means a straight line with slope 1 and an acceptable R-squared. The slope is 0.43 meaning that, for a one percent increase in the share of Malaria cases, the intervention share on average increases by 0.43 percent ($R^2=0.09$). A slope of less than one implicitly means that, on average, higher burden countries are getting disproportionately less of the interventions.

By focusing on the top-10 countries based on the Malaria cases, we found that 8 of them are receiving an intervention share less than their disease burden share. For example Nigeria (5% of interventions for 23% of Malaria cases), Democratic Republic of the Congo (0.7% for 10%), Kenya (4% for 5%), Uganda (0.05% for 4%), and Ghana (1% for 3%), Mozambique (2% for 3%) are high burden countries with significant unmet need. India (36% for 4%) and Ethiopia (9% for 5%) are two exceptions.

The huge gap between the need and interventions for high case countries has contributed to their deteriorating situation. The findings of this analysis suggest that donors need to revisit their investment schedules by re-allocating resources in favor of very high case countries. It is true that the real need, as WHO emphasizes, is much greater than what has been available so far and the intervention level for Malaria needs to grow substantially. However, even the completely budget-neutral test conducted in this analysis suggests a serious need to reconsider the level of need and re-allocate resources accordingly.

**Findings, Implications and Recommendations for Next Steps**

While there was a sharp increase in spending on Malaria by domestic and external sources of funds in at risk countries over the 2001-2007 period, the prevalence of Malaria cases and mortality did not decline proportionally. This phenomenon was articulated in the latest Malaria report (WHO 2008). WHO suggests that, although in a few countries the observed decline can be linked to specific interventions, in general the links between interventions and the trends in the illness remain ambiguous.

This study was conducted to diagnose some of the institutional problems in the global Malaria control system over past seven years by seeking to disentangle the relationship between Malaria trends, funding, and interventions. We considered a set of sequential causality paths in a closed loop fashion to simulate a Malaria control system. The Malaria system is amenable to a closed loop analysis because the feedback from significant variations in prevalence and mortality impacts funding. Two key characteristics of each casual path were examined: the efficiency and the lag which is defined as the delay time between consecutive events. In this analysis, we posited that the existing global Malaria control system is suffering from a poor level of efficiency and that it reacts to trends in three separate steps.
Random-Effect models were used in order to explain the three paths of casual relations: from observation of the problem (Malaria cases) to spending behaviors, then from available funds to preventive/treatment services provision, and finally from services provided to final outcomes: Malaria cases. In the first two paths, the estimated elasticity was a proxy for the efficiency. As far as the lag of paths is concerned, the comparison of estimated coefficients for immediate and lagged variables in each model guided us to judge whether a cause-effect relation was the result of immediate variation in independent variables or the lagged variations (previous year variations).

We present the main findings and their policy and research implications

1. Trends in funding for Malaria
   - Over the last 4 years, total and external source funding for Malaria has been increasing. The rate of growth for external funds is higher and consistently significant compared with the rate of growth for government funds, which is lower and more often not significant.

   - The level of funding by donors increased sharply. In 2007, the total spent on Malaria was 6.3 times higher than the total spent in 2001, after controlling for covariates.

   - Countries with less effective governments relied more upon funds from external sources.

   - A limitation to consider is that private contributions to prevention and treatment of Malaria were not included due to lack of data.

2. Relationship between Malaria cases and funding
   - There is a positive relationship between the observed outcome (number of malaria cases) and the level of funds spent on Malaria. Malaria case counts (in logs) are positively correlated with funding (in logs). Overall, the Malaria case elasticity of total funds suggests that, if Malaria cases increase by 1%, total Malaria funds will increase by 0.27%. However, it appears that external funding of donors is more sensitive to the variation in Malaria cases. A 1% increase in Malaria cases stimulates a 0.45% increase in donor funds. Government funding for Malaria is not as sensitive to fluctuations in Malaria trends.

   - The average level of government funds available for Malaria (12.7) is much greater than the level of available donor funds (7.23) in a logarithmic scale.

3. Relationship between funds and coverage
   - There is an additive effect for funds from the previous year and the same year. We call this effect a ‘steady state spending elasticity of coverage.’ Our results showed that, when total funds for Malaria increase by 1% and, if that increase is
sustained for two consecutive years, procurement will increase by 0.22% from the same year funds plus 0.19% from previous year funds. Therefore, the steady state spending elasticity of coverage is 0.41%. This is still well below unitary elasticity, indicating low efficiency and a delayed effect of funds. The interaction of the two elasticities from paths one and two results in a low number (0.11), meaning that, with a 10% increase in prevalence of malaria, the number of ITN+LLIN procured will be increased only by 1.1%.

- While a rapid response to outbreak is recommended by literature, not all effects on procurement were observed immediately in the same year. The total funds spent on Malaria in any given year and in the previous year can jointly increase the procurement of nets.

- Donor funding in the previous year can significantly increase the procurement of nets, but the same year donor funds do not show a significant effect.

- There has been an increasing trend of coverage since 2005. In the year 2007, 2.8 times more nets were delivered than in 2001, after controlling for covariates.

- There was a delay in time from fluctuations in prevalence (where the feedback is formed) to the time that services reach the at-risk population. The estimates of models 1 and 2 neither supported the expected level of services (relative to the size of problem) nor the requested speed of interventions. In other words, preventive and treatment interventions were too little too late to control Malaria effectively, particularly in very high prevalence countries that vastly rely upon donor funds.

4. Relationship between coverage and Malaria cases
   - There was no significant relationship between the coverage factors and the number of Malaria cases when all countries studied together. Neither the coverage factor nor the health system indicators explained the fluctuations in Malaria universally across all countries.

5. Divergence
   - Two clusters of countries exist. One cluster had a lower number of Malaria cases and did an acceptable job controlling Malaria. Another group with a high number of Malaria cases has been experiencing an increase in disease prevalence over time.

   - The coverage factor is not an important contributor in controlling Malaria in countries with a low number of cases. However, the coverage factor can significantly decrease the prevalence of Malaria in high case countries.

   - In the cluster with a low level of cases, the effect of health systems reduces the number of Malaria cases. This is not true for the high case cluster.
In the high case cluster, rainfall significantly increases the number of cases. In low case countries, the effect of rainfall was negative. This seems unusual and is most likely due to unobserved factors.

Within the high prevalence group, the proportion of countries performing poorly is 61.1%. In the low prevalence group, 14.7% performed poorly.

Twenty-six and a half percent of countries are following a deteriorating trend. Moreover, the trajectory of these countries (if they have high number of cases) could be pulling the global trend accordingly.

Eight of the 10 countries with the highest cases are receiving less than their fair share of interventions based on their level of disease burden. This is contributing to the divergence phenomenon. The slope of the line showing the distribution of interventions based on need was 0.43 percent. A line with slope 1.0 indicates a ‘fair share,’ thus, the distribution of interventions to the 8 countries is disproportionately low.

Simulations were conducted to create three scenarios of future Malaria trends. The optimal scenario suggests that the 10 countries with the highest number of cases should receive vigorous, targeted intervention in order to reverse the deteriorating trend. This could result in Malaria cases decreasing to 70 million world-wide by 2020.

Policy and research implications

1. A New Funding Strategy
A significant change in cyclical trends of Malaria is not likely to occur as long as the funding strategy continues to be reactive. The existing global model of reactive funding that follows a sudden outbreak in disease appears to explain a significant amount of the inefficiency in the current system. While increased funding might produce some desirable results, significantly better results may be achieved if more effective funding strategies were in place. Cyclical and reactive funding cannot support infrastructure development, which is a constant need. Cyclical funding also does not take advantage of the benefits the economy of scale and the productivity associated with learning-by-doing that contribute to improvements that are achieved over time. Assuming greater efficiency is attainable, maintaining funding levels over time (at a minimum) or, ideally, steadily increasing funding over time, will make reaching the critical thresholds (i.e., 70% for IRS) much more likely.

A paradigm shift is needed to address the critical issues of efficiency and timing. The existing post-hoc funding strategy should be abandoned in favor of sustainable budgets for preventive programs that are established for a period of years. A program with a long time horizon and steady or rising funds will help ensure the recommended thresholds for
both preventive and curative modalities. A commitment for sustainable financial resources should include a sustainable surveillance mechanism to ensure improvement of efficiency to an acceptable level. Investment in reporting systems is also crucial. Without reliable reporting systems in high prevalence areas, international health research will not be able to provide the right and timely policy recommendations.

Recently, there have been some concerns in the global health industry around the crowding-effect emerging from too much attention to HIV/AIDS interventions. Although the burden of Malaria according to the WHO report remains high and combating Malaria is relatively more cost effective than AIDS, the latter is consuming a lion-share of funds available for global health interventions. This factor might explain the modest responsiveness of donors to unexpected rises in Malaria prevalence.

Recommendations

- Additional cross-country quantitative analysis is needed to gain a better understanding of the gaps in the effectiveness of current funding and intervention policies and to make recommendations for improvements at the donor level.
- Malaria programs should be designed with a long time horizon that includes steady or rising funds.
- Sustainable surveillance mechanisms should be developed to improve efficiency.
- Reporting systems are needed to support the development of more effective and timely policy decisions.

2. Functionality of health systems suggest differential approaches: vertical versus horizontal

The estimate of the health system strength proxied by the public expenditures suggests that, in the low Malaria case cluster, functionality of the health system reduces the burden of Malaria. This effect is not proven for the high cases cluster.

Approaches to delivering services aimed at preventing and treating Malaria cases should be structured based on the system capabilities of countries. High prevalence countries that have weaker health systems would benefit most from vertical programs to distribute interventions to people in need. Conversely, those countries with stronger health systems are likely to be able to effectively use their existing health system to deliver care.

While some of the variations in disease cases were explained in the third path model, a significant portion of the trend remains unexplained. Malaria experts have argued that to reduce the prevalence of Malaria, it is crucial that a minimum threshold in each modality be met and that the right combination of modalities (prevention and treatment together) should be implemented widely to insure the desired results. As an example, CDC (2008) strongly recommends that, to be effective, IRS must be applied to a very high proportion of households in an area (usually >70%). In addition to the preconditions in supply side and delivery system, the demand side also plays a critical role in minimizing the underutilization of the effective interventions. Unless all constraints from different levels
discussed by Hanson et al (2003) are overcome, the group of deteriorating countries may not be able to bring the Malaria under sustainable control.

Initial findings on the comparative effectiveness of the malaria control programs in two clusters suggest that the criteria that differentiate the clusters are beyond the scope of the delivery system and even health system as a whole. Some higher level preconditions at the stewardship level and even further at the government level might add to the explanation of the variation in the supply side of the Malaria programs. The differences in literacy, voice and purchasing power of at risk population in each country probably can explain the demand side variations. For a control system to be effective, the preconditions in all levels have to be understood and addressed properly. Such systemic approach to a high burden and unpredictable disease like Malaria is more probable than existing disease-based approach, to attain the MDGs by 2015.

Recommendations

- In depth country case studies aimed at dissemination of best practices from the former group is much needed to help individual countries in the poor performer group combat Malaria more effectively. Only by studying the efficacy of control efforts within individual countries can a complete understanding of the constraints to success be achieved (i.e., funding, health system, climate, environment, and epidemiological constraints).
- In countries with high Malaria cases and weaker health systems, vertical programs should be considered. In countries with lower cases and stronger health systems, interventions can be diffused through existing health systems.

3. More focus is needed for the ten countries that are on a deteriorating path

A crucial finding that emerged from the path 3 (Coverage-Prevalence) was a distinct divergence from the mean of two groups. The finding on divergence was reaffirmed by cross-tabulating countries according to prevalence and performance. A group of high prevalence countries was on a deteriorating path and a group of low prevalence countries was on an improving path. The significance of the diverging behavior of the two clusters of countries over time was statistically approved yet less is known about the differential factors contributing to this. Although our model estimates suggested a relation between the climate condition in terms of the rainfall in the high prevalence cluster, the fact that the average rainfall in two clusters is comparable and even a bit higher in the low case countries suggest that there are other factors contributing to the diverging trends other than unpredicted climate conditions.

When the high risk countries reach the critical thresholds in service provision and manage to maintain that level for a long enough period of time, they move from a strategy of Malaria control to a higher level of Malaria elimination. The uncertainty and cost of reaching the higher levels of elimination and even the prevention of reintroduction will be much lower once the infrastructures and technical competency have been built.
Our study also suggests that the Malaria burden has an extremely uneven distribution, i.e., 64% of Malaria cases were identified in only 10 countries. Moreover, 8 of the 10 countries in this group are receiving disproportionately less intervention for Malaria than they should, based on their disease burden. The combination of the higher distribution of the burden of disease and the unfair distribution of resources and plus the high aid dependency of these countries calls for a serious re-examination of aid practices. The ambitious MDG goals to combat Malaria do not seem attainable in the foreseeable future unless the donor community revises its practices.

Recommendations:

- The recommended case studies should focus on identifying best practices for vertical intervention programs that have worked to control Malaria. These studies should also include an examination of context-specific barriers within the 10 countries where Malaria is currently not adequately controlled in order to strategize ways to improve program effectiveness.
- Financial support and long-term commitment must be maintained to control Malaria in high case countries.
- An increase in financial support is needed as soon as possible for the 10 countries that account for more than 64% of the global burden.
- The gap in distribution of interventions must be closed to bring the 8 countries up to a level of intervention that is consistent with their disease burden.
- Increase investments in vertical programs in high Malaria case countries.
- Use context-specific knowledge gained from case studies to increase the efficiency of funds and decrease the delay in distribution of services to populations at risk.
- This is the first study that attempts quantitative, multi-country analysis that links the number of malaria cases with funding and the level of interventions. Data inadequacies exist in each of these areas. There is a need for discrete studies to fill the information gaps.

Acknowledgements

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country-year level; Chinedu O. Agbakwuru, M.D., M.S. for his help organizing the rainfall data, and Joanne Beswick, M.A., for editing.
References:


Annex:

Vector control and treatment modalities for Malaria

Vector control modalities for Malaria

Three of the most common modalities of vector control for the prevention of malaria will be assessed here. Vector control aims to decrease contacts between humans and vectors of human disease. Control of mosquitoes may prevent malaria as well as several other mosquito-borne diseases. A brief definition of each according to Center for Disease Control and Prevention (CDC 2008) follows:

Insecticide-Treated Bed Nets (ITN):

ITNs are a form of personal protection that has repeatedly been shown to reduce severe disease and mortality due to malaria in endemic regions. In community-wide trials in
several African settings, ITNs have been shown to reduce all-cause mortality by about 20%. The application of a residual insecticide greatly enhances the protective efficacy of bed nets. The insecticides used for treatment kill mosquitoes and other insects. The insecticides also have repellent properties that reduce the number of mosquitoes that enter the house and attempt to feed. In addition, if high community coverage is achieved, the numbers and longevity of mosquitoes will be reduced. When this happens, all members of the community are protected, regardless of bed net ownership. To achieve such effects, high community coverage is required, as for indoor residual spray.

**Long-Lasting Insecticide-treated Nets (LLINs)**

More recently, several companies have developed long-lasting insecticide-treated nets (LLINs) that retain lethal concentrations of insecticide for at least 3 years. The WHO Pesticide Evaluation Scheme has recommended five of these LLINs for use in the prevention of malaria.

**Indoor Residual Spraying**

Many malaria vectors are endophilic, resting inside houses after taking a blood meal. These mosquitoes are particularly susceptible to control through indoor residual spraying (IRS). As its name implies, IRS involves coating the walls and other surfaces of a house with a residual insecticide. For several months, the insecticide will kill mosquitoes and other insects that come in contact with these surfaces. IRS does not directly prevent people from being bitten by mosquitoes. Rather, it usually kills mosquitoes after they have fed, if they come to rest on the sprayed surface. IRS thus prevents transmission of infection to other persons. To be effective, IRS must be applied to a very high proportion of households in an area (usually >70%).

As a result of the cost of IRS, the negative publicity due to the failure of the Malaria Eradication Campaign, and environmental concerns about residual insecticides, IRS programs were largely disbanded in all but a few countries with resources to continue them. However, the recent success of IRS in reducing malaria cases in South Africa by more than 80% has revived interest in this malaria prevention tool. It has also reignited the debate over whether or not DDT should have a place in malaria control. With support from the Global Fund to fight AIDS, Tuberculosis and Malaria (GFATM) as well as the President’s Malaria Initiative (PMI), several countries have initiated IRS programs—many using DDT in their arsenal of insecticides—for the control of malaria.

Many countries have adopted a combination of approaches, where nets are sold through the private market and also distributed at no cost or heavily subsidized to groups at risk of severe malaria (pregnant women and children under 5). Balancing these strategies so that they complement each other may prove to be the best way to rapidly increase coverage among vulnerable populations while ensuring that this very effective malaria control intervention is sustained over the long term (CDC 2008).

**Treatment Modalities for Malaria:**
WHO recommends the use of artemisinin-based combination therapies (ACTs) in order to ensure high cure rates of Plasmodium falciparum malaria and to reduce the spread of drug resistance mosquitoes. The majority of falciparum endemic countries have adopted ACTs as first-line treatment and deployment of ACTs in the public sector has increased exponentially during the past 3 years. In the private sectors, however, the artemisinin derivatives are mainly marketed as monotherapies, and their consumption, if unabated, will promote development and spread of resistance and compromise the effectiveness of ACTs.

Since April 2001, WHO has recommended the use of ACTs in countries where Plasmodium falciparum malaria is resistant to chloroquine, sulfadoxine-pyrimethamine and amodiaquine. ACTs ensure the highest cure rates and have the potential to reduce the spread of drug resistance. At present, 60 countries have adopted ACTs as recommended by WHO, and 33 are deploying ACTs in the general health services. With increased mobilization of international funds, mainly from the GFATM, the procurement of ACTs for the public health sector has increased exponentially during the past three years, with more than 30 million ACT treatment courses procured and delivered in 2005. However, in the private sector markets of endemic countries, artemisinin derivatives are used more widely, mainly as monotherapies at lower prices compared to ACTs. Only 11 countries with falciparum-resistant malaria do not currently allow marketing of artemisinin monotherapies (Afghanistan, Brazil, Eritrea, Iran, Mexico, Malaysia, Philippines, Saudi Arabia, Sudan, South Africa and Thailand) (WHO 2006). As the latest World Malaria Report (WHO 2008) indicates, by June 2008, all except four countries and territories worldwide had adopted ACT as the first-line treatment for P. falciparum. Free treatment with ACT was available in 8 of 10 countries in the South-East Asia Region, but a smaller proportion of countries in other regions.

**Health system factors that affect efficiency of Malaria control efforts**

The Commission for Macroeconomics and Health recommended a significant increase in resources for health in poor countries, in order to increase access to (‘scale-up’) priority health interventions among the poor. However, money alone is unlikely to be sufficient to address the constraints facing health systems (Hanson et al., 2003) as a broad range of factors currently impede the delivery of adequate health services, only some of which are amenable to alleviation through the injection of additional resources (Ranson et al. 2003).

Ideally, the measurement of constraints should be exhaustive insofar as it should capture each of the five levels of constraints described in Hanson et al. (2003) (See Table 1 in this Annex for more details on 5 levels of constraints). However, variables capable of proxying levels III (health sector policy) and IV (cross-sectoral policy) for a cross-section of low and lower-middle income countries have proven elusive. Ranson et al. (2003) therefore limited their analyses to three dimensions: community/household level; health service delivery; and overall environment (See Table 2 in this Annex for more details on variable used to classify countries).
Ranson et al. (2003) found substantial heterogeneity across the 84 low-income and (all) sub-Saharan African countries analyzed. Poor sub-Saharan African countries are the most highly constrained; Asian countries, in general, less constrained; and the two Asian giants, China and India, consistently fall above the median. Former Soviet Union countries rank low in terms of governance, but high for health systems variables. Some of the major indicators determining level of constraint in Ranson et al. study were as following: GDP per capita for financial constraint, women literacy for community/household level, nurses per population, vaccination coverage, and access to health services for health system delivery, control of corruption and government effectiveness as environmental characteristics.
Table 1: Constraints to improving access to priority health interventions, by level according to Hanson et al. (2003)

<table>
<thead>
<tr>
<th>Level of constraint</th>
<th>Types of constraint</th>
</tr>
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</table>
| I. Community and household level                 | Lack of demand for effective interventions  
Barriers to use of effective interventions (physical, financial, social) |
| II. Health services delivery level               | Shortage and distribution of appropriately qualified staff  
Weak technical guidance, programme management and supervision  
Inadequate drugs and medical supplies  
Lack of equipment and infrastructure, including poor accessibility of health services |
| III. Health sector policy and strategic management level | Weak and overly centralized systems for planning and management  
Weak drug policies and supply system  
Inadequate regulation of pharmaceutical and private sectors and improper industry practices  
Lack of intersectoral action and partnership for health between government and civil society  
Weak incentives to use inputs efficiently and respond to user needs and preferences  
Reliance on donor funding that reduces flexibility and ownership  
Donor practices that damage country policies |
| IV. Public policies cutting across sectors       | Government bureaucracy (civil service rules and remuneration; centralized management system; civil service reforms)  
Poor availability of communication and transport infrastructure |
| V. Environmental and contextual characteristics  | Governance and overall policy framework  
-Corruption, weak government, weak rule of law and enforceability of contracts  
-Political instability and insecurity  
-Low priority attached to social sectors  
-Weak structures for public accountability  
-Lack of free press  
Physical environment  
-Climatic and geographic predisposition to disease  
-Physical environment unfavourable to service delivery |

Source: Hanson et al. (2003), Table 1
<table>
<thead>
<tr>
<th>Level</th>
<th>Variable</th>
<th>Indicator</th>
<th>Year</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial constraints</td>
<td>Lack of demand due to insufficient purchasing power; weak health system infrastructure due to low levels of private/public spending</td>
<td>GDP per capita PPP (current Intl. $)</td>
<td>1998</td>
<td>(World Bank, 2000)</td>
</tr>
<tr>
<td>Community/household</td>
<td>Lack of demand for effective interventions due to lack of information and low levels of education</td>
<td>Female literacy</td>
<td>1999</td>
<td>(UNDP, 2001)</td>
</tr>
<tr>
<td>Health services delivery</td>
<td>Shortage and maldistribution of appropriately qualified staff</td>
<td>Nurses /100,000 population</td>
<td>1989–99</td>
<td>(World Health Organization, 2002b)</td>
</tr>
<tr>
<td></td>
<td>Weak systems for managing supplies, staff, information</td>
<td>DPT3 coverage</td>
<td>Multi-year mean (1990–2001)</td>
<td>(World Health Organization, 2002a)</td>
</tr>
<tr>
<td></td>
<td>Lack of equipment and infrastructure, poor accessibility of health services</td>
<td>Access to health services</td>
<td>1985–95</td>
<td>(UNICEF, 2002)</td>
</tr>
<tr>
<td>Health sector policy</td>
<td>None</td>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cross-sectoral policy</td>
<td>None</td>
<td>Control of corruption</td>
<td>2001</td>
<td>(Kaufmann et al., 2002)</td>
</tr>
<tr>
<td>Environmental characteristics</td>
<td>Corruption, weak government, weak rule of law and enforceability of contracts</td>
<td>Government effectiveness</td>
<td>2001</td>
<td>(Kaufmann et al., 2002)</td>
</tr>
<tr>
<td>For sensitivity analysis:</td>
<td>Weak systems for managing supplies, staff, information</td>
<td>% case detection of new smear positive cases</td>
<td></td>
<td>(World Health Organization, 2002c)</td>
</tr>
<tr>
<td>Health services delivery</td>
<td>Geographic constraints</td>
<td>Proportion of the population in the geographic tropics</td>
<td>N/a</td>
<td>(Gallup et al., 2001)</td>
</tr>
</tbody>
</table>

Source: Ranson et al. (2003), Table 1