The Economics of Life and Death: Rethinking Our Battle with Malaria in a New Era of Disease Control

Author: Kevin Meme

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Kevin B. Meme

BOSTON COLLEGE

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Table of Contents

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ABSTRACT

Malaria kills over 3,000 people each day—mostly in sub-Saharan Africa—and remains the world's number one killer of children under five. While efforts to combat the disease were largely successful in past decades, eradication has since stalled as the parasite (and its mosquito vector) have retreated to the core tropics and become increasingly resistant to pesticides and anti-malarial drugs.

This study seeks to determine what other factors are significant in producing high malaria rates, and, based on those results, to offer policy suggestions that may provide alternatives to the "traditional" methods of combating malaria. The project uses cross-country models and individual country models of malaria output to analyze country indicator data and household survey data from around the world. Empirical analysis reveals that foreign aid flows may be less significant in reducing malaria outputs than originally suspected. Furthermore, the data suggests that other factors such as political stability, access to goods and services, and the use of bednets perhaps demand greater attention than they currently receive.

THE ECONOMICS OF LIFE AND DEATH

“This is an unacceptable situation on our planet.”

– Jeffrey Sachs, April 2002

To the thousands who die each day in Africa, and the thousands more who fight to save them.

PART I

INTRODUCTION

The Question

If people in the United States were asked to list the diseases and ailments that most concern or worry them, it is unlikely that malaria would be at the top, or anywhere near the top. It is possible, in fact, that malaria would not even make the list, and for good reason. Those who live in most of the industrialized nations of the world, outside of the tropics and away from the jungle, do not have to worry about malaria. Unless, that is, they decide to travel to places like sub-Saharan Africa, where malaria is arguably the biggest problem—the greatest scourge in people's lives.

What is interesting, however, is that the malaria problem is not simply a matter of geography. It is certainly not the case that the United States or Europe has never suffered its own malaria epidemics. (A brief history of the disease can be found below.) What *is* true is that, somewhere during the twentieth century, many industrialized countries, through new drugs and increased knowledge, found ways to combat the disease, and made it a thing of the past.

But it is not a thing of the past for many. In fact, malaria remains the world's number one killer. And while developed nations send billions of dollars each year in aid to malarial-endemic countries, eradication efforts have stalled. In many ways, the blight of malaria has been overshadowed by other things, such as the more recent AIDS epidemic—an issue with which developed nations seem much more concerned. Today, eradication of malaria is treated as impossible; all efforts focus on substantial reduction[1]. Yet even reduction seems very difficult to achieve. The recently formed "Roll Back Malaria" (RBM) campaign is evidence of this. The Roll Back initiative is a partnership of every major international

[1] In fact, the goal of the multilateral "Roll Back Malaria" initiative is to halve the world's malaria burden by 2010. Four years into the program, it appears unlikely that RBM will reach that target.

organization, as well as NGOs and government agencies; it is an attempt to pool resources—money, knowledge, personnel—to fight a disease that, in other times and other places, has seemed so easy to defeat. The question, then, is simple: why?

Can History Repeat Itself?

Perhaps a sense of history is helpful.[2] While seen as primarily a tropical disease today, it is widely believed that European settlers are to blame for malaria's introduction into North and South America. Near the same time however, Jesuit missionaries in South America discovered the anti-malarial properties of the Cinchona tree's bark. By the mid-1600s, the bark was in wide use in Europe. Two hundred years later, it would be discovered that quinine is the active ingredient in the medicinal tree.

Malaria was prevalent in North America from the 1700s right up to the twentieth century. One of the first military expenditures of the Continental Congress in 1775 was for $300 to buy medicine to treat malaria in Gen. George Washington's troops. An outbreak of malaria was reported as far north as Ottawa in 1828, and during the Civil War, 50% of white soldiers and 80% of black soldiers were infected with malaria each year.

It was not until the late 1800s that the malaria parasite was first seen under a microscope. This discovery led to much discussion about the transmission of the disease. In 1898, many people's suspicions were confirmed, when the malaria parasite was tracked through a mosquito, and the insect was identified as the vector for the malaria parasite.

The Centers for Disease Control and Prevention reported over 600,000 cases of malaria in the United States as late as 1914, and by World War II, a search for a new drug to treat the disease was begun in earnest, as supplies of natural quinine ran low. Eventually,

[2] An interesting, if not uplifting, source of information on the history of malaria is Robert Desowitz's book *The Malaria Capers: More Tales of Parasites and People, Research and Reality* (1991, W.W. Norton & Co.)

this led to the development of two drugs, mefloquine (the synthetic version of quinine) and chloroquine (another synthetic drug). Up to the present day, these two anti-malarials have been the most widely prescribed treatment for the disease (see information on the malaria life-cycle, below).

With the knowledge that mosquitoes act as vectors for malaria, new efforts to combat the disease became possible. Most developed nations were able to essentially eradicate the disease via a four-pronged approach: (1) the use of anti-malarial drugs, (2) drainage of standing water to eliminate mosquito breeding grounds, (3) liberal spraying of insecticides such as DDT, and (4) improvements in the screening of homes to prevent mosquitoes from entering living spaces. Current efforts to combat the disease still center around these four basic “traditional” tactics. Such a strategy involves attacking both the parasite (anti-malarial drugs) as well as the vector (insecticides, drainage, and screening).

Unfortunately, it appears that many strains of the malaria parasite have become highly (or completely) resistant to chloroquine and mefloquine. In addition, the World Health Organization conducted wide-ranging studies and experiments during the 1950s and 1960s testing the effectiveness of DDT on mosquito populations, and thus, the rate at which malaria was spread. In many cases, mosquito populations and malaria rates dropped significantly during the years of spraying, however discontinuation of the experiments resulted in the eventual resurgence of mosquito populations. Furthermore, more recent concerns about pesticides’ detrimental effects on the environment have led to a number of government restrictions on the use of DDT. Finally, many species of mosquito have become extremely resistant to conventional pesticides in recent years.

All of this has led once again to a search for new weapons to combat malaria. Between 1955 and 1970, the United States Agency for International Development (USAID) alone gave over $1 billion to the World Health Organization for research into malaria. Today, most of the research efforts are geared toward developing a vaccine for the disease—an accomplishment that still seems many years in the making. Perhaps the most recent and exciting news came in 2002, as the malaria genome was finally entirely decoded. Researchers hope this will open new doors to finding cures for the disease, and a shift in focus seems to be underway, as efforts are now directed more toward combating the malaria parasite itself, rather than killing the mosquitoes that carry it. It remains to be seen whether history will repeat itself, and malaria will be eradicated from endemic countries, as it was years ago in the United States and elsewhere.

The Problem

But just because eradication and new knowledge about malaria remains beyond the horizon, it is not the case that the current malaria problem is one about which nothing can (or should) be done. At the 2002 Harvard International Development Conference, famed economist Jeffrey Sachs proclaimed the extent of the malaria problem to be "an unacceptable situation on our planet." As mentioned above, malaria is the world's number one killer. Conservative estimates place the death toll from the disease at about 3,000 per day, more than one million each year. However, recent numbers place the malaria burden as high as 7,000 deaths each day, and more than 2.7 million each year. What is perhaps most upsetting is that the vast majority of these deaths occur in pregnant women and in children under the age of five. In fact, malaria is the leading cause of death in young children in sub-Saharan Africa. Geographically, fully 90% of malaria cases and deaths occur in Africa, south of the Sahara desert.

It is estimated that malaria causes well over 300,000,000 cases of acute illness each year. All of this adds up to serious consequences on many fronts. First and foremost, the death toll is simply too large to comprehend. Second, such a disease burden makes for dire economic results. Roll Back Malaria calculates that malaria costs Africa $12 billion (USD) annually, and that the continent suffers a 1.3% growth penalty per year as a result of the disease. While just over one percent does not seem much, economists appreciate the power of marginal changes. Had malaria been eradicated in 1960, Africa's GDP today would be 32% higher than it is presently. This does not even mention the loss in potential human capital that comes from such early deaths. Finally, macroeconomic statistics do not capture the burden of the disease on the household level, where malaria is not only a financial drain, but an emotional one as well.

Unacceptable indeed. Unacceptable because, at present, there may be low-cost measures available to us that have the potential to greatly reduce the strain that malaria places upon people. From low-cost anti-malarial drugs, to the use of bednets, to simple efforts at educating people about the disease, malaria is not a disease to be fought only in the laboratory. Many suggest that, by a simple increase in funding from donor nations and organizations, a renewed effort at reducing the malaria burden can be successful.[3] With many NGOs and international organizations working on the ground in malarial-endemic countries, the question begs itself again. What are the specific conditions and obstacles in these countries that are preventing significant reductions in the incidence of malaria? And more importantly, if traditional drugs and pesticides have become ineffective, what new methods might be effectively employed in the world's second great attack on malaria? In response to these questions, this project proposes some hypotheses. Many of these

[3] More about funding is found in a discussion of hypotheses in Part II.

hypotheses are based upon more specific information about the malaria parasite, its vector, and their life cycles.

The Biology of Life and Death

A digression is most appropriate here to discuss some specifics and to answer some common questions. While the mosquito often gets much of the blame for the disease, it is the malaria parasite that is the true culprit. The parasite comes in a variety of strains, some of which are more lethal than others. The most (in)famous form of the malaria parasite is *plasmodium falciparum*. It is also the most deadly, and is found widely in the malarial-endemic countries of sub-Saharan Africa. Each strain of malaria produces a slightly different pattern of symptoms. In fact, around 500 B.C., Hypocrites classified the fever from malaria into three categories: "quotidian" (daily), "tertian" (alternate days) and "quartan" (every fourth day).

When a human is infected with malaria, the parasite heads directly to the liver. There, it incubates for a number of days, maturing and reproducing. Eventually, the parasite leaves the liver and enters the bloodstream. Once in the blood, the parasite invades red blood cells, which it uses to further multiply itself. This inevitably lyses (bursts open) the red blood cells, releasing new parasites that head to the liver to repeat the process. This alternating process of incubation and invasion is what causes the on-and-off fevers of malaria. Symptoms occur during the destruction of cells in the bloodstream, and subside during periods of incubation.

Note that, although many tropical ailments are carried by mosquitoes, the symptoms and life-cycle of malaria are not to be confused with diseases such as Dengue fever or the West Nile virus. Dengue is usually less serious than malaria, but can become increasingly more serious after multiple infections. The West Nile virus, on the other hand, can only infect a human once. West Nile also targets mostly the elderly and those with weak immune systems. Malaria is almost always fairly serious, and can be acquired multiple times. Furthermore, regardless of age, it almost always causes acute illness.

Another important difference in malaria is the lack of a third party vector. Transmission of the disease occurs from mosquito to human and from human to mosquito. Thus, there is no other pest supplying the parasite to mosquitoes.[4] Such a fact leads to the somewhat hopeful conclusion that, conceivably, humans have a great ability to interrupt the deadly cycle on our end by preventing bites.

As mentioned above, anti-malarial drugs have historically been quite effective in beating the disease. In fact, such drugs do no prevent infection, but simply kill the parasite soon after it infects the human. In addition, it should be noted that some degree of resistance or partial immunity can be acquired if one suffers from (and survives through) an episode of malaria at an early age.[5] Finally, the genetic disposition for sickle cell anemia is most likely an evolutionary adaptation for fighting malaria. Those bearing the sickle cell gene harbor a degree of resistance to malaria.

The life cycle of the mosquito is certainly better known than that of the parasite it carries. There are, however, a few important facts to mention in relation to combating malaria. The primary vector for the malaria parasite is a species of mosquito known as *anopheles gambiae*. While mosquitoes breed in standing water, species such as *gambiae* do not need much. In fact, a hoof print fullof water can be enough to sustain an infectious population of mosquitoes. Mosquitoes generally bite as dusk, and it is only females that bite

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[4] One will recall recent outbreaks of the West Nile virus in the United States, in which it was discovered that birds and other animals can pass the disease along. Thus, while a suspicious dead bird in your backyard was a good warning sign, controlling the virus became a bit more complicated.

[5] An obvious ethical question is then raised about whether or not it is wise to allow a certain population to be exposed to the disease, in the hopes that they will develop resistance.

humans for a meal. In most species of mosquitoes, biting is immediately followed by a period of resting to allow for digestion. When used properly, the pesticide DDT (dichlorodiphenyltrichloroethane) is effective in interrupting this cycle. DDT is meant to be applied to the inside surface of dwelling spaces, as opposed to being sprayed into the air outside. When a mosquito rests on a DDT-treated wall, it will die. A similar series of events occurs in the use of insecticide-treated bednets. The nets, which are generally used for sleeping, are usually dipped in permethrin, another lethal insecticide. Thus, when the mosquito lands on the net in an attempt to get at a human, it will be killed. Other insecticides are not lethal, but act simply as an irritant to the mosquito. One popular example of this is "deet" (N, N-diethyl-m-toluamide), the active ingredient found in over-the-counter insect repellants.

A complication that deserves mentioning is the existence of species of mosquitoes that do not follow the above pattern. Certain mosquitoes do not enter living spaces, nor do they rest immediately after biting. Since they remain outdoors and constantly moving, these mosquitoes are, in some ways, more difficult to handle. In other ways, however, they are more easily avoided by remaining indoors.

The biology of life and death is important to our understanding of malaria. It not only helps conceptualize the problem, but also assists in developing hypotheses about the significant obstacles to anti-malaria efforts. Ultimately, they may lead to new ideas about how best to fight the disease.

This paper is organized as follows. Part II discusses a theoretical approach to the problem by describing various hypotheses linking malaria to a variety of factors on the macro and micro level, and by explaining general theoretical models. Parts III and IV describe the data being used and test these relationships through cross-country and intra-country empirical work, respectively. Section V presents conclusions and policy implications of the results.

Part II

THEORETICAL CONSIDERATIONS

Hypotheses

The discussion above can only leave one with a number of questions, as well as a number of ideas. This paper presents a variety of hypotheses that one might suggest based on what we already know. It is these theories around which the empirical data work of the project is centered. The hypotheses may be roughly divided into micro and macro concepts.

It was mentioned previously that funding for research, development, supplies, etc., is a major issue. Looking at the levels of foreign aid flows is the first major hypothesis. Presumably, greater amounts of foreign aid, as well as perhaps more focused allocation[6] will lead to lower malaria rates. Furthermore, the availability of drugs, especially in rural areas, may be greatly limited.

Availability brings to light two other hypotheses: rural location, and the quality of transportation infrastructure. Both of these factors can affect whether or not one has the proper supplies to deal with an illness. Poor roads and a remote location may not only affect the delivery of drugs but also the transportation of food, water, hospital supplies, and any number of other important needs.

Three hypotheses center on specifically human factors. First, the extent of government corruption and political instability may affect a country's ability to fight disease. If foreign aid money is siphoned away before reaching those in need, corruption can be a very significantly negative factor. Further, political instability can mean that long-range projects are constantly changing and/or never finished. The second hypothesis regards family structure. Presumably, a two-parent household can deal with disease burdens more

[6] For example, much money may be being wasted on drainage efforts that are doomed to be ineffectual. As mentioned above, such a small amount of water is necessary that an entire country would have to be paved over and kept free of puddles for drainage to be effective. Perhaps this money is better spent on other projects.

easily than a one-parent arrangement. For a woman with a number of children, caring for the sick can be a full-time job. If the mother is also required to work and earn an income, this can put great strain on her ability to take her children to the doctor, or get them proper care. A two-parent household may allow more flexibility in this regard, as well as providing a more steady income.

Finally is the education hypothesis. As can be seen from our discussion of the disease, its history, and its life cycle, proper human action may be the crucial link in fighting malaria. And knowledge and education about the disease is an essential first step. When the West Nile virus created a scare in the United States, there was a quick educational response in the form of news information, town meetings, etc. This allowed people to learn what times of day they should remain indoors, what type of clothing to wear, what insect repellants to use, drainage techniques, etc. With malaria, such education is even more valuable, given the simple two-way cycle between humans and mosquitoes.

Education is not just about knowing when to remain inside, however. One interesting example comes with regard to bednets. There is much to know about using a bednet, including the proper technique for cleaning it and dipping it in permethrin to re-treat it. However, another problem not often recognized is the presence of holes. While nets are generally effective in blocking mosquitoes, one hole can be deadly. A torn net can mean that many mosquitoes get through the net, but then cannot find their way out, becoming trapped against the person's body. Without the proper education, some methods of fighting a disease can become counter-productive.

Finally, one would hope to be able to account for any "Africa effect," "tropics effect," or other factor that is based purely on geography. That is, one's location hopefully does not have significance in and of itself, but only insofar as a given location implies other significant conditions. However, the effect of the tropics is interesting and somewhat mysterious. It is true, for example, that the majority of highly indebted poor countries (HIPCs) are located in the tropics and that the majority of tropical countries are quite poor. However, it is unclear whether being in the tropics actually causes one to be poor. In terms of malaria, there is an even more interesting dynamic. Most every malaria-endemic country is poor, but establishing a causal relationship is more difficult. Does being poor cause high malaria rates because of a lack of financial resources to fight the disease? Or does having malaria prevalent in a country drain resources, capital, and productivity, and thus cause deeper poverty?

It is these various and diverse hypotheses that form the central parts of the analytical work of the project. Now, it is important to mention some specifics about methodology and data sources.

In Theory: Modeling

Perhaps the best way to determine significant factors in the malaria problem is to think of a malaria production function:

$$Y_{malaria} = X_0 + \ldots + X_n$$

Where $Y_{malaria}$ is some measure of the "output" of malaria and X_0 through X_n are vectors of inputs, which will be described below. However, the question of what might constitute an appropriate "output" for such a function demands a short digression.

After an extensive search for relevant data, and after much research into previous work on this problem, it was discovered that, at present, there is very little reliable data on malaria incidence rates from country to country. This is certainly in part attributable to a lack of capacity for data collection in many poor countries. Recently, with the advent of the

RBM campaign, a multilateral effort to collect good data on infectious diseases like malaria is beginning to pick up steam.

As a result of this, however, one is forced to use other measures of the malaria burden, both on the macro and micro level. The data being used to look at intra-country factors in this study takes the form of various household and individual surveys that have been conducted by the World Bank and the U.S. Agency for International Development (USAID). As detailed below, each of these surveys is a bit different. Luckily, a few of the individual surveys include an optional set of questions classified as the "malaria module." Among other things, the malaria module asks a person whether or not he has had a fever in the past two weeks. Thus, the most common "output" for the malaria production function on the micro level will be a binary variable equal to 1 if the respondent has had a fever recently and 0 if he has not.

On the macro level, there is perhaps a bit more room for movement. The data being used to study factors at the national level is a conglomeration of various macro indicators from a number of sources, including the World Bank, Freedom House, and studies conducted through the Center for International Development (CID) at Harvard University. Among this last category is a crucial work by John Luke Gallup and Jeffrey Sachs on geography and economic development. While this work deals with a broader range of topics affecting economic growth, one of the most important factors hindering growth (as evidenced in the introduction) is the extent of infectious disease. To this end, Gallup and Sachs have created a variable—"malfal94"—to measure the intensity of malaria in a given country. Their description of the variable is as follows:

> "Because of lack of true malaria incidence or prevalence data for the most severely affected countries, our index is necessarily approximate. We digitized a world map of the extent of

> malaria in 1994 [shown in Figure 5] from the World Health Organization (WHO 1997), and used GIS [Geographical Information Systems] to calculate the fraction of a country's land area subject to malaria, excluding the areas of 'limited risk.' To quantify the differing intensity of malaria, we collected WHO (1992) data for 1990 on the percent of malaria cases that are the malignant *falciparum* species of malaria, which, of the four species of malaria, has the most severe symptoms, is the most resistant to drugs, and is responsible for almost all malaria mortality. The malaria index is the product of the percent land area times the percent of *falciparum* cases." (Gallup and Sachs, 1999, p. 20)

Thus, Gallup and Sachs's measure of malaria intensity serves as an important way to quantify and grasp the extent of the malaria problem across countries.[7]

However, it is important to remember that the question this study addresses is not only concerned with reducing the extent of malaria's endemism. Ultimately, the "output" that is of most concern is the number of deaths due to malaria. Once again, reliable data on the number of deaths due to particular infectious diseases is difficult to come by across a variety of countries. However, we may be able to use measures of childhood mortality (i.e. death rates of children under 5 years of age), as good proxy variables. Recall that malaria remains, worldwide, the leading cause of death for children under five. Indeed, a simple regression of childhood mortality rates on Gallup and Sachs's malaria intensity index reveals an extremely close relationship:

$$\text{Child mortality}_{(<5,\ \text{deaths per 1,000 live births})} = \underset{(1.88)}{14.75} + \underset{(5.59)}{62.4}\ \text{malfal94}$$

$N = 46 \quad R^2 = 0.42$

This serves to emphasize the fact that lower outputs of malaria can be expected to be reflected in lower child mortality rates. Furthermore, one may control for other diseases to

[7] In reference to the index of malaria intensity, one may also see Figure 4, which gives a visual representation of the index across the world. One will certainly notice the much higher levels of intensity exhibited in sub-Saharan Africa—an issue discussed in greater detail in Parts III and V.

some extent, by including variables measuring vaccination rates. Thus, by using these two variables—malaria intensity and child mortality—we can assess the effects of various inputs reasonably well in the multi-national portion of the study.

On both the micro and macro levels, the inputs to the malaria production function are even more defined by available data than the outputs. For the individual country analyses in particular, the inputs are limited by the particulars of the individual and household questionnaires.[8] As stated earlier, each survey is a bit different. For example some include questions more specifically related to malaria, and others do not. The World Bank surveys do not ask a question about fever, but a more general question about illness. At the same time, the World Bank surveys are often more broad in the factors they assess, including, for example, such things as whether the person's dwelling has screened windows, or whether or not the respondent owns a watch.

In general, we may divide the inputs for the intra-country production function into four categories:

1. *Variables describing the respondent (R).* These would include such things as marital status, years of education, gender, age, etc.
2. *Variables dealing with health (H).* This category comprises vaccinations, money spent on health care, distance to health facilities, specific questions about sanitation, the use of bednets, etc.
3. *Variables related to the dwelling (D).* These are facts about the home, including the type of water source, the presence of screened windows, whether the home has electricity, etc.
4. *Location variables (L).* These would include facts like the distance to nearest road, the number of months the road is passable, and whether the respondent is located in a rural, urban, or suburban area.

[8] It should be noted that in many cases, the presence of missing values in the dataset can play a large role in determining what inputs appear on the right side of the equation. That is, oftentimes one particular input will have so many more missing values than others that it serves to greatly diminish the accuracy of the estimates. Sometimes it is not possible to include all of the desired inputs in the manner one wishes.

Thus, we have a general malaria production function for the micro analysis:[9]

$$P(Fever_{past\ 2\ weeks} = 1) = \beta_0 + R\beta_1 + H\beta_2 + D\beta_3 + L\beta_4 + \varepsilon_i$$

Many of the same issues are true for the cross-sectional analysis. For example, oftentimes particular variables will serve to limit the regression as a whole, due to a higher number of missing values. In the same way as the intra-country model, we can divide the macro data into a number of categories:

1. *Facts about the country (C).* These include many binary variables such as location (tropics, subtropics, etc.), continent, whether the country is landlocked, etc.
2. *Variables concerning health (H).* Such variables would include malaria intensity, government expenditure on health, vaccination rates, and so on.
3. *Education inputs (E).* Largely from Robert Barro and J.W. Lee's quality-of-education dataset, these inputs include government expenditure on education, pupil-teacher ratios, etc.
4. *Political factors (P).* These variables attempt to assess the stability of a country, by measuring, among other things, the extent of civil liberties, tabulating assassinations, and noting whether the country was formerly socialist, a colony, etc.
5. *Income data (I).* This set of inputs includes GDP, GDP per capita, volume of trade, amount of foreign aid received, etc.
6. *Demographic variables (D).* These variables comprise mortality rates, population density/location, illiteracy rates, etc.
7. *Measures of infrastructure (F).* These would include the percentage of paved roads, the number of telephone lines per 1,000 people, the number of TVs per 1,000, etc.

Thus, our general cross-sectional production function takes the form:

$$Y_{malaria} / Y_{childmort} = \beta_0 + C\beta_1 + H\beta_2 + E\beta_3 + P\beta_4 + I\beta_5 + D\beta_6 + F\beta_7 + \varepsilon_i$$

[9] Note that the inputs may be thought of as "investments in health," but not, perhaps, in the strictest sense. That is to say, some of the inputs may be such that a lower absolute value of the observation would correspond to a higher investment in health (e.g. time or distance to fetch water). Furthermore, many of the "investments" will take the form of binary variables. Being qualitative, these binaries cannot be thought of as "stock" or "flow" variables as might commonly be seen in a production function.

It is important to note that the cross-sectional portion of this study is quite different from the intra-country portion. First and foremost, the cross-sectional analysis uses macro statistics in an attempt to identify general trends that affect a country's output of health. Second, many countries (especially third-world countries and other HIPCs) do not have the capacity to keep detailed information or data about themselves, which means that much of the data collection is left to international organizations such as the World Bank. As described below, the World Bank indicators are the most reliable and extensive source of macro data available. Since the World Bank keeps tabs on about one hundred countries, the sample size in the cross-sectional portion is also considerably smaller than the single country analyses, which often used datasets with observations numbering in the thousands.

The final dataset that was used for cross-sectional analysis is actually a combination of data from a number of different sources, each of which is described below. The World Bank indicators provided the backbone of the dataset, and subsequent data was added appropriately.

PART III

The View from the Top

As alluded to above, the cross-sectional analysis employs a dataset of various macro indicators for over one hundred countries, located not just in sub-Saharan Africa, but also in South America, Asia, Europe, and North America. This dataset is actually the product of a number of separate data sources—each with its own focus—that have been merged together. Before discussing the tests performed on the dataset, it is important to describe the sources of the numbers in a bit more detail.

World Bank Indicators: The basic facts

Through the World Bank's online data query system, key socioeconomic indicators are available for over one hundred countries, going back over forty years. This set of indicators provides the backbone for the macro data used for the cross-sectional portion of the study. There are a number of disadvantages to the World Bank indicators, not least of which is the prevalence of missing values, especially for developing countries in earlier years of data collection. However, the World Bank indicators are in many cases the only reliable source of macro numbers for many countries that do not keep consistently good records on their own. Another positive aspect to the World Bank numbers is the ability to run tests for a variety of years. One can also, for example regress a variable like "percentage of malarial land in 1994" on numbers from years prior to 1994, to determine how previous years' policies affect present conditions.

The broad range of countries presented in the World Bank indicators is extremely helpful. One of the most interesting aspects to the malaria question is the particularly high rate of infection one sees in sub-Saharan Africa as opposed to other countries of similar climates but on different continents. The World Bank indicators give us data from various South American countries, a number of African countries, as well as south-Asian countries—all of which exist in climates potentially amenable for mosquitoes and thus, for malaria transmission.

The indicators cover a number of factors, from GDP to education, and mortality rates to transportation infrastructure. Thus they provide a reasonable set of variables to test the hypotheses put forth above.

Freedom House: Measuring governance and freedom

The independent think-tank and policy institution, Freedom House, publishes an annual “Freedom in the World” report, which assigns various “freedom scores” to countries based on a number of key categories: political rights, civil liberties, and freedom status. The factors that go into determining a country’s political rights status include: the existence of free elections; the ability for people to organize; and freedom from domination by military, foreign countries, or other powerful groups. The civil liberties factors include: freedom of expression and belief, organizational rights, human rights, the rule of law, personal autonomy, and economic rights.

For both political rights and civil liberties, Freedom House assesses the various sub-topics above and then assigns a number from 1 to 7, with 1 being the “most free” and 7 being the “least free.” These two scores are then averaged to provide Freedom House with the third score, “Free” (F) or “Not Free” (NF).

Using the Freedom House Freedom scores in conjunction with the World Bank indicators provides a good way to study the effects of a country’s political institutions on the health of its citizens.

Barro-Lee Education Data

Robert Barro and J.W. Lee compiled a useful dataset specifically focusing on international measures of schooling years and schooling quality. The dataset, obtained through the Center for International Development at Harvard University, contains measures of student-teacher ratios, current government educational expenditure per capita, repetition and dropout rates, and other such measures.[10] The Barro-Lee data allows one to focus more specifically on education as a potentially significant input in the malaria production function.

The data is especially beneficial to the cross-sectional portion of the study, as it takes a general look at education across a number of countries. The Barro-Lee data is available for most of the countries included in the World Bank indicator set.

CID Datasets: Growth, geography, and infectious diseases

Finally, two other datasets from the Center for International Development at Harvard serve to round out the macro indicators for this study. These datasets come from work by Jeffrey Sachs, et al. in two different papers that look at the sources of slow growth in African economies, as well as the dynamics between geography and infectious diseases. The first dataset is a rather diverse set of variables dealing with, among other things, assassinations, government spending, revolutions and coups, and life expectancy. The African growth data set also includes a dummy for the tropics as well as one for sub-Saharan Africa. These allow us to test for a geography or location bias in disease prevalence.

[10] Jong-Wha Lee and Robert J. Barro, "Schooling Quality in a Cross-Section of Countries," (forthcoming, NBER Working Paper, 1997) provides a more detailed explanation and sources of data. Also, see Barro, Robert and J.W. Lee, "International Measures of Schooling Years and Schooling Quality," AER, Papers and Proceedings, 86(2), pp. 218-223 and also see "International Data on Education," manuscript.

The geography and infectious diseases dataset provides a number of variables that are crucial to the macro analysis. Variables include specifics about climate, geography, and population density.

While the various datasets described above certainly have their shortcomings, they also provide a number of advantages. First of all, the data comes from reliable sources and covers a wide range of topics, from variables concerned with political institutions, to data focusing on education, health, and economic activity. This means that, when combined, the data allows for the testing of a number of hypotheses and consequently helps us approach the malaria problem from a number of different angles.

A Background Note

As mentioned in the Introduction, many of the questions this project seeks to answer are the result both of stalled eradication efforts, as well as the striking differences in malaria prevalence that we see across countries. The case of sub-Saharan Africa provides a good example. Maps like Figures 4 and 5 tell an interesting story. In Figure 5, we see that much progress has been made over the last five decades in eradicating malaria from many parts of the world. Indeed, in North America, Europe, Asia, and even South America, we see a great retreat in malaria risk. This is not true, however, in sub-Saharan Africa. The picture is even more stark in Figure 4, which depicts the malaria index. One cannot help but notice a few things. First, that malaria is not simply relegated to the geographical tropics (this is true presently, and also in a historical context as shown in Figure 5). Second, and more important, across countries and continents that lie on the same latitudes (and frequently have very similar climates), malaria risk differs greatly. One is instantly led to question why sub-

Saharan Africa seems to differ so markedly from the rest of the world in it's prevalence of malaria.

The regressions described below, as well as other maps at the end of this report, provide at least part of an answer. Figure 1 gives a visual representation of GDP per capita across the globe. It is evident that per capita incomes are far lower in sub-Saharan Africa than in most other parts of the world, including other countries located in the tropics. Figure 8 shows the percentage of population that lives in the tropics in a given region. Again, we see that the region of Africa south of the Sahara exhibits quite a higher proportion than even Latin America or South Asia. Finally, Figure 9 shows the degree of access populations have to coasts or rivers, which obviously facilitate trade, the delivery of supplies, as well as the mobility of people. While most places in the tropics (and in the areas of North America and Europe that were once plagued by malaria) have a high degree of access to a coast or river, Africa does not. In fact, it seems as if the whole interior of the continent is completely shut off.

One hopes that differences in malaria risk can be attributed to and accounted for by these vast differences in population dynamics, GDP, and even isolation. We will return later, however, to the question of sub-Saharan Africa, which remains a persistent one.

What the Data Says

A brief glance at the combined set of cross-country data causes a number of interesting relationships to jump out. Many of these relationships are depicted in the appendix of tables and graphs to this report, and they certainly raise questions in our minds without even running any regressions or solving any equations.

For example, one will note the incredibly wide range in incomes that shows up across nations. Gross domestic product, measured on a per capita basis, ranges from $465.19 at the low end (Ethiopia) to $27,323.18 at the high end (United States).

The numbers are perhaps most startling when one begins talking about location. Average GDP per capita is $3,496.80 in countries that are landlocked. Non-landlocked countries enjoy, on average, a GDP per capita over twice that of landlocked countries, at $7,141.18. Furthermore, while GDP is generally low in tropical countries, we see a further difference between GDP levels in the geographical tropics versus climatic tropics (see Figure 6). At every level, GDP measured by climate is lower than GDP measured by geography.

Indeed, the same is true for malaria. Using the malaria index described earlier, we see vast differences in malaria intensity between geographically tropical and climatically tropical countries. Of the thirty-two countries with a malaria index between 0.8 and 1.0, twenty-nine are located in sub-Saharan Africa.

Finally, we see similar results when looking at the mortality rates of children under five years of age. Figure 2 illustrates the highly positive relationship between increases in the malaria index and increases in childhood mortality.

A look at the regression results deepens the story. Tables 1 through 9 give the coefficient estimates (as well as the absolute value of their t-statistics) for the cross-sectional analysis of various factors' effects on the malaria index. Note that the first eight tables give results from regressions in which the independent variables were limited to one of the seven "classes" of factors, as described above. There is also one table describing the effects of climatic regions on the malaria index. Table 9 gives results for the models estimated using variables from all of the categories described in the first eight tables.[11]

Table 1a shows the effect of some basic country facts on the malaria index. Among other things, the dummy for sub-Saharan Africa and the effect of a location in the geographical tropics are highly significant. Table 2a isolates the effect of climatic regions on the malaria index. As can be seen, location in the tropics or sub-tropics produces significantly higher malaria index numbers. However, it is important to remember that, while these numbers suggest a certain degree of the "geography is destiny" conclusion, the coefficients do not suggest that climate explains the whole story. Furthermore, areas from which malaria was eradicated in past decades were largely climatically subtropical. These suggest that it is worth investigating other connections.

Table 3a reports a significant effect of government health expenditure on the malaria rate. This is not surprising, as one would expect that an increase in health services, especially to those in rural areas, might help in providing health supplies as well as more immediate care.

The results presented in Table 4a suggest that education factors may have a much less significant effect on malaria intensity than hypothesized. Government educational expenditure and enrollment rates are both only sometimes significant.

Perhaps Table 5a presents the most interesting results from the isolated factors. It appears that the political climate of a country has an impact on malaria rates that is worth our attention. Most strikingly, we see significant coefficients on the variables measuring

[11] Note that most of the regression tables contain more than one estimation for each variable. For each set of variables, a variety of models were estimated, for a number of reasons. First, it was often the case that the initial model being estimated did not contain enough observations, due to missing values, and thus had to be corrected. Second, in each model there is a degree of multicollinearity exhibited in the data, as many of the factors are closely related. Subsequent alteration of the model being estimated attempted to account for this problem by removing some of the "culprit" variables and obtaining more accurate (and often significant) estimates for other factors.

civil liberties and the timing of a country's independence. Recall that the civil liberties score is a value from 1 to 7, with higher numbers representing lower degrees of liberty. Similarly, the timing of independence variable takes on the values 0-3, with the higher numbers signifying more recent independence. The significant coefficients on both of these factors seem to verify some original suspicions. Countries that are subjected to corrupt governments, dictators, political instability, etc., are more likely to exhibit high disease rates. This may be due to the way in which public funds are distributed under such conditions—an issue that other figures (such as expenditure on education or health) may not be picking up. The numbers may also indicate that a country's resistance to outside help, expertise, and other resources may have a highly negative impact on its citizen's health. Indeed, countries that are newly emerging as independent states likely show signs of higher rates of diseases such as malaria in part because of their former oppression. However, this variable also suggests that newly independent countries may be burdened by other priorities that command a new government's time. As we know from experience with newly independent states, it is perhaps impossible for a new government to deal with every problem at once. If it is necessary to spend a great deal of time on, for example, a new constitution, the rule of law, etc., then health measures and disease eradication may take a back seat until the country becomes more established.

The effect of income factors on malaria is questionable. There is certainly some significance to the level of GDP per capita, and marginal importance to foreign aid flows. Since it is measured on a per capita basis, the significant result for GDP may allude to the importance of changes in the consumption decisions of a household or personal level that the macro analysis cannot easily quantify.

Table 7a tests the significance of a variety of demographic factors, including population density, and population location. It is important to note that location in an urban area seems to help reduce the output of malaria. We will see this fact more clearly illustrated in the micro data. However, we may conjecture here that urban location provides a number of advantages in fighting malaria, not least of which are greater access to health facilities; increased sanitation and drainage; and the immediate availability of goods such as bednets, antimalarial drugs, and even a variety of foods for great nutrition.

The suggestion that access to goods and services is significant in reducing malaria burdens is corroborated by Table 8a, which shows significant coefficient estimates for the variable "percent of roads paved."

Table 9a combines many of the variables from the first eight tables into a series of larger regressions. A few important conclusions result from the estimates displayed in Table 9a. First of all, there seems to be a degree of multicollinearity, as evidenced by the few significant estimates but the relatively high R-squared value. The subsequent regressions attempt to deal with this problem by dropping some variables that may be causing the multicollinearity. We can see that when this is done, variables such as civil liberties, timing of independence, percent of roads paved, etc. regain their significance. Secondly, there appears in all the regressions to be a strong "sub-Saharan Africa effect." Indeed, the existence of such an effect can be seen visually, as mentioned earlier. However, accounting for things like access to water, population, GDP, levels of education, and even political stability does not seem to make location in sub-Saharan Africa insignificant. It is disturbing to report that this fact seems to point at least in part to some unexplainable effect present in the prevalence of malaria. One is led to suggest the existence of other factors (potentially ones that are difficult to quantify) that keep this particular region of the world in desperate state when it comes to malaria.[12]

Before leaving the macro portion of the analysis, we must look at similar regressions performed using child mortality numbers as the dependent variable. While one would expect the results to be highly similar, given the relationship between malaria intensity and under-5 mortality, these regression estimates are perhaps more practical in terms of policy recommendations. While we are certainly concerned generally about the burden of disease and its adverse economic effects, it is undeniable that the worst consequence of high malaria rates is high death rates.

Table 3b analyzes health variables. The results place significance on immunization rates as an important aspect to preventing childhood deaths. Although this result is not directly related to deaths from malaria, it is certainly true that good health generally may be the best way to prevent death from malaria.

The results in Table 4b seem to show something a bit different from the regressions run on malaria intensity. Indeed, it appears that education factors such as government educational expenditure as well as pupil-teacher ratios are important in reducing child mortality. It is perhaps difficult to grasp the underlying concept, but these variables may serve as a kind of proxy for the amount of "individual attention" a child receives, both from the community around him as well as from state services generally.

As one would expect, the significance of the political climate on mortality rates follows closely with its significance in malaria intensity. It is not surprising that newly independent states and nations subjected to dictatorial rule and wars cannot ensure as high a level of health and safety for its people as more established and peaceful governments can.

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[12] A further discussion of the ramifications of the "sub-Saharan Africa effect" is found in the conclusions in Part V.

Income effects are also more significant in reducing mortality than in reducing the malaria rate (see Table 6b). Foreign aid flows, GDP per capita, and the degree of isolation from the coast all impact death rates. The same is true for urban location, as shown in Table 7b, and for the percent of roads paved (Table 8b).

Finally, the combined regression once again exhibits symptoms of multicollinearity. However, some variables remain notable, especially the measure of literacy in a country. In all regression estimates, higher illiteracy rates among the adult population serve to increase the death rates among young children. Given the high degree of dependence on adults among children under five, the significant illiteracy estimate may point (among other things) to parents' inability to be adequately informed about how to care for their children. Additionally, high adult illiteracy is certain to slow the learning process in children. Perhaps this helps explain the significant results seen in Table 4b.

When we combine the regressions on child mortality with the estimates for malaria output, we are certainly left with important policy implications. These will be discussed at length in Part V. However, our insights into the malaria burden do not now end with the results from this data. In order to develop a more clear understanding of the dynamics of the disease, as well as in order to make more intelligent policy recommendations, it is important to look at data on a smaller level. Individual and household survey data can shed light on other aspects of the "malaria production function" for which the macro data is simply too general to depict.

PART IV

ON THE GROUND

While country-level indicators can convey a great deal of important information about malaria and our efforts to control it, they do not tell the whole story. Indeed by its very nature, a macro analysis of the malaria problem is bound to miss some of what happens "on the ground." In an effort to better understand what factors lie behind malaria outputs, this study sought out data taken from individuals and households in addition to more general country indicators.

The micro, or intra-country, portion of this study has a number of advantages. First of all, it allows us to look at certain factors, such as individual health expenditure and bednet usage, that were not explored by the cross-sectional analysis. Furthermore, the datasets used in this part of the project are household and individual survey data from individual countries. This is important, since country-level indicators often gloss over regional differences in countries, opting for less-specific averages. The individual country survey data allows us to take a few countries as examples and to explore how differences in various inputs *within* a country may cause differences in the level of health and the "output" of malaria.

Below is a brief description of the data used in this portion of the study, followed by a presentation of results.

Living Standards Measurement Study (LSMS)

The Living Standards Measurement Study (LSMS) surveys are a series of studies conducted by the World Bank at the requests of individual countries. The LSMS program has been in existence since the 1980s, and new studies are ongoing. A number of the survey datasets are made available free of charge at the World Bank's LSMS website.[13]

[13] See www.worldbank.org/lsms

Each survey is slightly different, depending upon the country in which it was conducted, but all LSMS surveys collect data on various aspects of the household, including consumption, income, savings, employment, health, education, fertility, nutrition, housing, and migration. Each LSMS survey contains the household questionnaire that, in light of the "malaria production" model described above, was most crucial to this study. The household questionnaires collect data on health, income, housing characteristics, education, material possessions, and human behavior. LSMS also conducts a community questionnaire in some countries that collects information on the town in which the survey is being conducted, and contains information about the town's infrastructure, etc. Finally, LSMS occasionally includes a price questionnaire that records the current prices of a variety of commodities.

The LSMS surveys are helpful to this study for a number of reasons. First and foremost, given that good data on malaria and malaria infection rates is quite difficult to find, the LSMS surveys ask a few important questions that can shed light on these particular concerns. The Tanzania 1993 survey asks the question: "During the past 4 weeks have you had any illness or injury? For example, have you had a cough, a cold, diarrhea, an injury due to an accident, or any other illness?" While this question is not malaria specific, it is important to remember that, in a country in which malaria is a leading cause of illness and death, changes in the incidence of malaria will certainly be evident in the responses to this question. In many of the surveys, one also has the ability to control for other diseases such as tuberculosis, diphtheria, measles, and polio, since the survey sample can be specified to include only those people vaccinated against particular diseases.

Second, the large sample size as well as the broad array of questions in the survey allows for a meaningful model to be tested. The LSMS surveys are conducted on a nationwide basis, and thus data is collected from rural, urban, and suburban areas of a particular country. This makes data from LSMS particularly good for analyzing the malaria problem from within a particular country. One can create a model to determine what factors are significant in producing the different malaria "outputs" we see in different parts of the same country. And because of the variety of sections comprised in the survey, our model can test diverse variables (e.g. expenditure on health and distance from a paved road) at the same time.

Demographic and Health Surveys (DHS)

Sponsored by the U.S. Agency for International Development (USAID), the MEASURE program (Monitoring and Evaluation to ASsess and Use REsults) is a ten-year initiative aimed at institutionalizing the collection and use of data for countries, both for program monitoring and for policy formation. Demographic and Health Surveys are one aspect of the MEASURE program. The DHS surveys are nationally representative datasets, usually consisting of between 5,000 and 30,000 households. The questionnaires focus on obtaining data on population, health, and nutrition. While the standard survey consists of both a household questionnaire and a women's questionnaire, DHS also contains a variety of country-specific "modules," based on specific requests by the host country and by USAID. Thus, a few DHS surveys contain a detailed set of questions concerning malaria, including questions about the use of bednets and the use of common anti-malarial drugs.

The Demographic and Health Surveys were chosen for this study for a number of reasons. First, the MEASURE DHS program is recognized across disciplines as an extremely accurate and up-to-date source for data on issues regarding health, population, and nutrition. Furthermore, the large, nationally representative sample size once again allows for a meaningful study of how intra-country differences in the inputs of the malaria production function affect the output. Finally, the specific malaria module of the DHS surveys, while only used in a few countries, contains questions specific to the disease that are simply not found in other more general surveys and datasets.

Some Reverberant Facts

Perhaps the most startling revelations from the micro data are found not through regressions, but by an even more simple look at the numbers. These numbers give us insight into the ways in which people live their lives day to day in each particular country, and they certainly suggest ideas for change.

In terms of medical treatment, some interesting facts are worth noting. In Benin, a small country in sub-Saharan Africa, 84% of people sought medical attention for their fever within 3 days, but only 41% sought attention within 1 day. This is significant since we know that malaria becomes much more deadly, especially in children, after 24-48 hours. In Burkina Faso, 60% of people received no treatment for their most recent fever or cough.

Perhaps the most startling facts can be found with regard to bednet prevalence and treatment. In Colombia, 68% of people do not have a bednet for sleeping. Of those who do own a bednet in Colombia, some 23% reported that no child slept under the net last night. And in Malawi, a country that could not be more malarial-endemic, almost 83% of respondents had no mosquito nets in the house.

An important aspect to the effectiveness of bednets is whether or not the net has been treated with insecticide (most commonly a pesticide called permethrin). In fact, bednets need to be treated with permethrin regularly to remain highly effective. In Colombia, 90% of people have received no treatment of their bednets since obtaining them; and in Malawi, 61% of those who have a bednet have never had it dipped in permethrin.

Finally, some interesting differences can be found when one compares rural and urban areas. In Benin, 56% of urban dwellers own a bednet, while only 37% of rural homes do. Also, urban residents in Benin are four times more likely than rural inhabitants to have screened-in homes.

All of these facts point clearly to some very practical problems, and perhaps suggest some more policy ideas. First of all, it appears that bednet prevalence is not nearly as high as one would hope or expect, especially in countries that are so threatened by diseases borne by mosquitoes. Secondly, there seems to be a lack of follow-up or education about the use of bednets. This is evidenced not only by the significant number of people that claimed they do not use the bednet, but also more clearly by the immense number of those who have never had their net treated with permethrin.

Finally, the urban-rural dichotomy is very important. It is obvious that rural areas are from the outset more susceptible to diseases such as malaria for a variety of reasons, including decreased access to goods and services, as well as to less thorough drainage of standing water. One would hope, then, that efforts to distribute bednets would focus more intensely on rural areas. However, it seems that bednets have not reached rural inhabitants in large numbers. If one takes into account the lack of other advantages such as screened windows and access to health facilities, rural inhabitants of malarial-endemic countries are at a gravely high risk for contracting the disease.

Much of this information is supported by the regressions presented in Tables 11-13. Table 11 highlights a number of significant factors using data from Benin. We see that the possession of a bednet reduces the likelihood of fever by more than six percent. A similar regression on data from Malawi yields similar results:

$$P_{(\text{fever in past two weeks})} = 0.475 - .055(\text{mosquito nets in house})$$ [14]

The same is true for an urban location. An even greater affect is seen in those homes that have screened windows. Table 11 shows that inhabitants of such dwellings are some fifteen percent less likely to contract a fever.

Also, as one would expect, receiving vaccinations for other diseases (in this case, diphtheria) reduces the likelihood of fevers as well. While the vaccination variable is certainly significant because it causes reductions in fevers from diphtheria, it may also point to the value of generally good health levels in reducing illness from diseases like malaria.

Finally, the Benin data shows a noticeably significant estimate for the literacy variable. This variable can take on three values, with the highest representing the most literate. In line with the education hypothesis suggested earlier, higher levels of literacy seem to contribute to lower levels of illness.

Interestingly, the data becomes much less conclusive when one looks at two South American countries, as opposed to sub-Saharan African Benin. Indeed, the factors mentioned above are only marginally significant in Tables 12 and 13. This disparity raises another question by suggesting that the same policy choices may not be effective in different places.

Although much of the household and individual survey data collected was incomplete or did not cover the range of topics described in the model, there are still various important conclusions to be drawn on the single-country level. Perhaps most noticeably, the survey data reveals more specifics about the distribution and use of bednets in households

[14] The variable is binary: 0 = no mosquito nets in the house, 1 = yes, mosquito nets present. The regression is a “dprobit” model and thus the coefficient is the change in P given a change from 0 to 1 in the independent variable.

that the country-level indicators cannot expose. Secondly, a basic glance at the numbers from a variety of countries suggests both that rural inhabitants are at more grave risk and that individual human choices (e.g. the choice to seek treatment) can play a significant role in how we attack malaria and illnesses generally.

Other contributions of the survey data include the importance of vaccinations (and thus presumably of general good health). Also intriguing is the significance of the literacy variable in the Benin regressions. It is not entirely clear how something like literacy plays into a lower probability of fever, but it may act as a good proxy for education on an individual level. If this is the case, one is drawn back to the idea that education about a disease and its practical prevention methods is crucial to lowering infection rates.

Part V

CONCLUSIONS

So after sorting through all the numbers and tables, what do we have to say about our efforts to battle malaria? More importantly, does the data suggest any important implications for policymakers or any other individual involved in the fight against this disease?

Well, first this report reminds us of some key facts about malaria and how the disease works. These facts are important to keep in mind as one moves forward to develop policy suggestions. The transmission process of the malaria parasite involves only two actors: humans and mosquitoes. Thus, we are alerted to the importance of human action in breaking the infection cycle of malaria. Furthermore, because the parasite is borne by mosquitoes, malaria thrives in tropical areas, especially in the core tropics where mosquito populations have a strong and more permanent foothold. Recall that it is an incredibly small amount of standing water that is necessary for sustaining an infectious population of mosquitoes. Indeed, it appears that early efforts to eradicate malaria, largely through the use of pesticides, have halted in part because the malaria populations in the core tropics are better established. However, maps like Figure 5 also seem to point to the fact that, over time, both mosquito and parasite have become increasingly resistant to "conventional" weapons such as pesticides and anti-malarial drugs.

We also saw, however, the malaria is not simply an issue of geography. Maps of malaria risk reveal vastly different levels of disease burden across countries located in the same climatic regions. Furthermore, despite parasitic resistance to drugs and vector resistance to pesticides, we have seen virtually no come back of the disease in places where it was once endemic and has since been eradicated.

These facts, combined with the empirical work of the project lead us to a number of conclusions that run counter to original hypotheses. First of all, given the increased resistance to pesticides, as well as taking into account recent environmental concerns raised over the use of chemicals such as DDT, efforts that focus highly on eradication of malaria through the pesticide killing of mosquitoes are perhaps misguided. At best, they exhibit a poor decision in allocating scarce funds and resources.

Second, in areas that are consistently tropical, effective drainage efforts may be nearly impossible to achieve. Especially in rural areas, eliminating standing water to the point that infectious populations of mosquitoes are significantly reduced is almost certainly impractical. On the other hand, just as was the case with diseases such as the West Nile virus outbreak in the United States, individual drainage of small standing water locations in and around the home is likely a wise preventative measure. Indeed, if any money is to be invested in drainage efforts, one would hope that such initiatives would focus on such "backyard" breeding grounds as opposed to large-scale drainage projects.

Third, another hypothesis—that of family structure—appeared to be less significant than expected. Although the data is not of the highest quality, there does not seem to be a significant relationship between more "stable" two-parent households and lower malaria outputs.

Finally, the presence of a "sub-Saharan Africa effect" remains a consistent problem. As discussed, sub-Saharan Africa exhibits higher malaria intensity and child mortality rates than any other region in the world, be it tropical or not. This study attempts to account for a variety of things that may explain this effect, including political factors, income levels, issues of trade and access to markets, etc. However, after including these various factors in regressions, the dummy for sub-Saharan Africa remained significant. There is certainly more that can be done to analyze this effect. One important aspect that this study does not examine is the composition of the malaria intensity index itself. It may be the case that much of Africa's high malaria and mortality rates is due to the specific strain of malaria parasite present in the region. Unfortunately, good data on this is not readily available. However, one may immediately question the claim that the concentration of *plasmodium falciparum* entirely explains the sub-Saharan Africa effect. A simple glance at some of the figures at the end of this report reveal countries with very high malaria intensities that border other countries (in the same climatic region) with relatively low malaria intensities. While *falciparum* concentration may explain some of the differences in malaria intensity that we see across continents, it may not explain differences that show up within smaller regions.

Another hypothesis regarding this effect is the presence of some underlying, perhaps unmeasured, bias against sub-Saharan Africa. For example, are experts from other countries unwilling to travel to the region? Are incentives to work and live in sub-Saharan Africa (and thus help the region) too low? Are there specific cultural traditions present in the various African societies that alter human action and place people at higher risk of disease? All of these questions are left for further discussion, as each deserves a serious examination.

However, the empirical work of this project also suggests some interesting policy options on the positive side as well. We saw in regressions on malaria intensity as well as on child mortality and the prevalence of fever that a variety of factors seem to play into lower malaria outputs.

Perhaps most striking is the importance of bednet distribution and use in reducing malaria rates. While the country level indicators more or less skip over specific data on bednets, the micro level analysis revealed some instructive facts. First of all, regressions including the possession of a bednet estimate a significantly negative coefficient on the dummy variable (i.e. owning a bednet causes reductions in the probability of having a fever). But in many countries there is a startling low distribution rate of bednets, especially in rural areas. Furthermore, survey data revealed that a great number of people own bednets that have either never been treated with permethrin insecticide, or that have not been treated nearly as often as is necessary. Finally, we see that many people who reported owning a bednet consequently reported that no one slept under the net in the previous night.

All of these facts point to a need for increased focus on bednet distribution and education. Rural areas—already at higher risk of malaria infection—are gravely deficient in access to bednets. Moreover, it appears that many people are not aware of proper insecticide treatment methods for their net, nor are fully aware of the benefits of using a bednet on a nightly basis. If this is true, one might also infer that the problem of holes in bednets (discussed in the introduction) is something that must also be addressed in any good distribution/education initiative.

A second policy suggestion centers around access to goods and services and openness to trade. By simply looking at Figure 9, one can see that sub-Saharan Africa is unique in that the entire interior of the continent is shut off from access to the coast or navigable rivers. Perhaps this is one reason why we see drastically higher malaria rates in Africa south of the Sahara than anywhere else in the tropics. Aside from navigable waterways, the issue of access to goods and services can be illustrated by looking at the rural-urban dichotomy. It is clear from the data that residents of urban areas are better suited to protect themselves from malaria than rural inhabitants. This is certainly due in part to the greater degree of access urban dwellers enjoy to products such as bednets and services such as professional healthcare. It is no surprise then, that the macro analysis showed the variable for the percent of paved roads to be a significant factor in reducing malaria outputs. Indeed, the time required for delivery of supplies or transportation to a health facility is highly dependent on the quality of infrastructure such as roadways.

The problems with bednets and access to goods and services illustrate an even more fundamental problem: that of individual human action. As mentioned at the outset, the malaria parasite is passed exclusively between humans and mosquitoes. One would then expect a kind of positive feedback mechanism to take place. If less people are infected with malaria, less can pass the parasite back to mosquitoes, and thus even less mosquitoes can in turn hand it on to humans, etc. Yet, while human action is so evidently important to reducing malaria outputs, we consistently see responses that represent poor decisions. There are high numbers of people not using their bednets, and even more who do not handle their nets properly. Furthermore, we saw very few people report that they had used an anti-malarial drug for their most recent fever. Indeed, many people did not even seek medical attention for their most recent illness until after a number of days had passed. This is problematic in that the intervening days between the time of infection and the time of treatment allow for a strengthening of the disease as well as open the door for further transmission to a mosquito population.

To go back to the example of West Nile virus, one of the most successful strategies used to combat the disease was a widespread education program, that employed the news media as well as many local town meetings. It was here that people were able to gain information about the warning signs of the disease, learn practical ways they could prevent infection, etc. Some such education initiative could indeed be very helpful to people living in malaria endemic countries.

Results from the data also serve to support another hypothesis: the importance of political stability on health output. In fact, we found very significant estimates for variables such as a country's civil liberties score, colonial status, and timing of independence, all indicating that more established and more "free" societies enjoy lower malaria rates generally. The same results were seen when such factors were regressed on child mortality instead of malaria intensity. In both cases, increases in civil liberties and a greater degree of "establishment" in a country appear to exhibit health benefits for the country's inhabitants.

These results suggest, of course, that less free societies are ones in which the health of the people is not a prime investment for the government, or in which other factors such as internal strife, revolutions, and a lack of political stability lead to policies that are ever-changing and produce conditions that are not conducive to general welfare, good health, or valuable healthcare. Furthermore, countries that are newly independent may have a whole host of other concerns with which to deal at the present moment before they can begin worrying about health issues. It is likely true that they also lack available resources to devote to concerns such as health programs. Whatever might be at play underneath these results, it is clear that policies that encourage political stability, civil liberties, and political freedom lead to a more healthy society, by allowing a country to begin to invest in its people without the worries of war, revolution, etc.

One factor that turned out to be much more significant than expected was that of location within a country (i.e. whether one lives in an urban or rural area). Some of the largest and most disturbing numbers were seen when one looked at the urban/rural disparity within countries. In general, those in urban areas own more bednets, and (as discussed above) enjoy greater access to goods and services. And urban areas report consistently lower malaria and fever rates than rural regions. In fact, given that rural areas are already at greater risk of disease (due to the poorer drainage and lower degree of access to goods and services), it is unfortunate that more policies do not focus on rural inhabitants. To be sure, any good and effective program for bednet distribution, drug treatment, sanitation, etc., must take into special consideration those living in rural areas.

As has been alluded to already in this section, this report also included a series of regressions looking at child mortality, as opposed to malaria intensity. This choice is important, since the ultimate end of any disease eradication effort is that of reducing deaths. Since malaria most afflicts children under five, looking at child mortality rates is beneficial for forming policy suggestions. As was hoped, the results from these regressions were for the most part consistent with those that used malaria intensity as the dependent variable. These results are encouraging in that they suggest that the policy ideas gained from regressions on malaria intensity will also serve to reduce deaths. Most significant in reducing child mortality were education factors, degrees of political stability, and income measures such as GDP per capita and aid dollars per capita. Perhaps these areas take precedence in deciding what policies should receive funding and support.

Perhaps a note here on emerging ideas is also worthwhile. It is evident that this project seeks largely to point one in the direction of helpful policies or initiatives that may be undertaken to reduce the malaria burden, given the significant factors reported by the data. However, a new and growing body of literature has taken a different approach to combating disease (indeed, to combating poverty in general). This approach is in large part born out of environmental concerns as well as cultural concerns, and seeks to bring the focus of development policies back to the local environment. It is argued that policies initiated from "the outside" (e.g. those that deliver food from the developed world, or those that bring in outside experts) may have detrimental effects to the local agricultural environment as well as the local cultural environment. This new approach argues that much of the disease burden in poor countries comes as a result of generally low health levels and poor immune systems that allow diseases such as malaria to ravage a population. Proponents of this position suggest that disease and poverty is better fought by using local resources, which are often much more rich than the outside world realizes. The method focuses on using local crops that are, in a sense, "meant" to grow in a particular country, as a way to preserve the fertility of the land as well as create a more "comfortable" policy to local peoples. The policy also stresses employing the knowledge of local people, especially knowledge of medicinal plants, etc. All of this is geared toward fostering a generally higher level of health and life among the people by using their own resources. The advantage, of course, is that such an approach is perhaps more sustainable after the "outside experts" go home.[15]

Finally, this project would be remiss if it did not point out the number of considerations that have been left out of this discussion. To be sure, the issues surrounding the eradication of malaria are complex, and may be view from a number of angles, using immense varieties of data. In many instances, topics left out of this study were not included because of the difficulty in finding extensive, reliable, or otherwise usable data. Further investigation of the sub-Saharan Africa effect has already been discussed at length. However, it is hoped that this project sparks an interest to pursue some other topics further. Each deserves a close look.

[15] Those interested in further reading on this approach might turn to Stacia Nordin's recent article, "Malawi is Not a 'Poor Country' " in the 2002 (XVII) issue of *Praxis*, the Fletcher School's Journal of International Development.

First, while it is true that the malaria parasite has grown in resistance to anti-malarial drugs, it is also the case that such drugs still provide an important level of protection against the disease. Indeed, visitors to malarial countries from the developed world do not worry a great deal about malaria, since they can easily afford a supply drugs to ward off the parasite for a given period of time. Drugs such as chloroquine, however, are not necessarily cheap. A six-week's supply of chloroquine costs $30 in the United States. While that is a reasonable price for those of us with high per capita incomes, drugs costs in the poorer countries where malaria is endemic could put such needed medication out of reach for most people. A very interesting study would center on drug prices and availability in the developing world. Looking at the ratio of the costs of medication and health care to average household incomes could yield some interesting conclusions about how we fight malaria.

Second, the historical importance of pesticides such as DDT in reducing mosquito populations may merit a closer examination. Including variables such as whether or not a government has imposed DDT restrictions might be helpful in determining the significance of pesticides to an anti-malaria campaign. Another variable that would be instructive is some measure of the resistance of mosquitoes to pesticides in a given area.

Finally, the macro data from the World Bank and other sources allows one the ability to regress current conditions on previous years' policies. If one is interested in investigating more closely the time effects of certain policies, this might be a good place to start. Changes over time in the past may yield important insights in to policy options for the future.

APPENDICES

APPENDIX 1: REGRESSION TABLES

This appendix contains the empirical results of regressions run on the country-level and survey data. Many of these tables are referred to in the preceding analysis, but others are left for the reader to study and interpret. Please also refer to the footnote on page 29 for an explanation of the multiple estimations presented in many of the tables.

For the convenience of the reader, a double asterisk (**) has been tagged to those variables significant at the 5% level. Also, unless otherwise noted, the absolute value of the t-statistics appears in parentheses.

Regressions on the household data take the form of probability estimations, in which the dependent variable is a dummy, and the coefficient estimates can be interpreted as changes in the probability of "success" (= 1) in the dependent variable.

Finally, please see Appendix 2, below, for a more detailed description of each of the variables that appear in these tables.

Table 1a. The Effect of Basic Country Facts on Malaria Intensity

	(1)	(2)	(3)	(4)
Country is a former colony	-.019 (0.56)			-.019 (0.57)
EU dummy	.039 (0.64)	-.324** (3.07)		.023 (0.37)
Landlocked	-.036 (0.90)			-.037 (0.89)
Latin America dummy	-.378** (6.42)			-.342** (5.75)
%Land within 100km of coast or river	-.001 (1.93)		-.004** (4.23)	-.001 (1.83)
Sub-Saharan Africa dummy	.352** (5.86)			.394** (6.54)
South Asia dummy	-.072 (0.84)			-.125 (1.44)
Southern Hemisphere dummy	-.050 (1.11)			-.060 (1.29)
%Land in geographical tropics	.217** (2.90)			
%Land in climatic subtropics	.369** (4.27)			.533** (7.94)
%Land in climatic tropics	.343** (3.25)			.548** (6.76)
Constant term	.053 (1.16)	.324 (9.37)	.454 (9.03)	.066 (1.42)
Observations	122	149	149	122
R^2	0.85	0.06	0.11	0.84

Table 2a. The Effect of Climatic Regions on Malaria Intensity

%Land in climatic Temperate desert	.078 (0.31)	%Land in climatic Tropical/subtropical desert	.256 (1.43)
%Land in climatic Dry temperate region	.059 (0.28)	%Land in polar region	.327 (0.51)
%Land in climatic Subtropics	.682** (3.84)	%Land in climatic Tropics	.945** (5.24)
%Land in climatic Wet temperate region	.114 (0.61)	Constant term	-.120 (0.76)

N = 148; R^2 = 0.53

Table 3a. The Effect of Health Factors on Malaria Intensity

Health Expenditure per capita (US$)	-.0002 (0.74)	Total Health Expenditure (% of GDP)	-.052** (2.32)
DPT immunization rate (% children under 12)	-.006 (1.21)	Measles immunization rate (% children under 12)	-.005 (0.90)
Constant term	1.45 (8.23)		

N = 67; R^2 = 0.41

Table 4a. The Effect of Education Factors on Malaria Intensity

	(1)	(2)	(3)
Daily newspapers per 1,000 people	.0004 (0.23)	.001 (1.22)	
Government ed. expend. (primary school, per pupil, 1990)	-.0007 (1.14)		
Government ed. expend. (secondary, per pupil, 1990)	-.0004 (0.15)		-.0002** (4.52)
Illiteracy rate (Total adult pop.)	-.003 (0.87)	.002 (0.76)	
Radios per 1,000 people	-.001 (1.92)	.0001 (1.16)	
Tertiary school enrollment (% Gross)	-.017 (1.72)	-.030** (3.97)	
Televisions per 1,000 people	-.002 (1.02)	-.001 (1.78)	
Constant term	1.25 (5.77)	.703 (5.37)	.470 (7.82)
Observations	34	72	70
R^2	0.66	0.49	0.23

Table 5a. The Effect of Political Variables on Malaria Intensity

	(1)	(2)	(3)	(4)
Number of assassinations per million pop. per year	.059 (0.15)	.014 (0.04)		
Country a former colony	.201** (2.74)	.213** (2.88)	.064 (0.86)	.061 (0.83)
Civil liberties score (Freedom House, 1-7)[16]	.147** (2.23)	.152** (2.28)	.062** (2.57)	.059** (2.59)
Timing of independence[17]	.121** (2.83)	.091** (2.28)	.063 (1.71)	.063 (1.72)
Political rights score (Freedom House, 1-7)	-.051 (0.98)	-.044 (0.84)		
Number of revolutions and coups per year	-.147 (0.96)	-.146 (0.94)		
Socialist economic system dummy	-.179 (1.25)	-.378** (4.12)		
Transition economy dummy	-.314 (1.79)			
Had an external war (1960-1985)	-.146 (1.39)	-.103 (0.99)	-.035 (0.38)	
Constant term	-.178 (1.70)	-.191 (1.80)	-.064 (0.68)	-.060 (0.64)
Observations	79	79	119	120
R^2	0.47	0.44	0.14	0.14

[16] One being the highest level of civil liberties, and 7 being the least amount of liberty
[17] (0=before 1914, 1=between 1914 and 1945, 2=between 1946 and 1989, 3=after 1989)

Table 6a. The Effect of Aid, Income, and Trade on Malaria Intensity

	(1)	(2)
Aid per capita (US$)	.0004	.003**
	(0.25)	(2.82)
Kilometers to closest major port	.00004	.0001**
	(1.39)	(3.17)
GDP per capita (1995)	-.0001**	-.0001**
	(4.50)	(4.49)
Ratio of real government expenditure to real GDP	.450	
	(0.71)	
Trade (as % of GDP)	.001	
	(0.14)	
Constant term	-.525	.212
	(2.46)	(1.74)
Observations	42	87
R^2	0.47	0.38

Table 7a. The Effect of Population Dynamics on Malaria Intensity

	(1)	(2)	(3)
Coastal population density (people per km^2)	.001 (1.09)	.001** (2.32)	.001** (2.30)
Inland population density (people per km^2)	-.0003 (0.65)		
Average population density (people per km^2)	-.001 (1.18)	-.001** (2.52)	-.001** (2.50)
Population in 1995	-.0004 (1.61)	-.001** (2.58)	-.001** (2.61)
% Population within 100km of coast or river	.002 (1.47)		
Rural people per km^2	.00002 (0.72)	.00004 (1.05)	
% Population in geographical tropics	.616** (4.95)	.526** (4.74)	.502** (4.62)
% Population urban (1995)	-.010** (5.11)	-.010** (5.00)	-.010** (5.39)
Constant term	.574 (3.75)	.672 (4.89)	.724 (5.64)
Observations	84	84	84
R^2	0.60	0.59	0.58

Table 8a. The Effect of Infrastructure on Malaria Intensity

	(1)	(2)	(3)
Daily newspapers per 1,000 people	-.0004 (0.25)		
Radios per 1,000 people	-.00001 (0.27)	-.00002 (0.29)	
% Roads paved	-.004** (2.12)	-.004** (2.11)	-.007** (4.65)
Telephone mainlines per 1,000 people	-.0005 (0.28)	-.001 (0.78)	
Televisions per 1,000 people	-.001 (0.97)	-.001 (1.06)	
Vehicles per 1,000 people	-.002 (0.88)	-.002 (0.98)	
Constant term	.787 (10.87)	.777 (11.58)	.708 (10.97)
Observations	70	75	79
R^2	0.37	0.38	0.22

Table 9a. Combined Effects on Malaria Intensity

	(1)	(2)	(3)	(4)
Latin America dummy	-.169 (0.77)	-.180 (0.96)		
Sub-Saharan Africa dummy	.273** (2.14)	-.240** (2.37)	.334** (4.30)	
% Land in climatic tropics	.333** (2.36)	.321** (2.56)	.377** (3.29)	.432** (2.26)
Total health expenditure (as % GDP)	-.031 (1.37)	-.015 (0.81)	-.020 (1.22)	-.014 (0.51)
Government ed. expend, 1990 (Secondary school, per pupil)				.0002 (0.75)
School enrollment, tertiary (% Gross)	-.005 (0.75)	-.006 (1.18)	-.001 (0.18)	
Civil liberties score (1-7)	.049 (1.38)		.071** (2.63)	
Timing of independence	-.004 (0.06)	.030 (0.48)		.288** (3.91)
GDP per capita, 1995	$-6.17e^{-06}$ (0.28)	$-2.81e^{-06}$ (0.18)	$7.05e^{-06}$ (0.48)	
Aid per capita (US$)	.0004 (0.29)	-.0003 (0.21)		
Kilometers to nearest major port	-.00001 (0.40)	-.00002 (0.78)		.00004 (1.29)
% Population in geographical tropics	.008 (0.06)			
% Population urban, 1995	-.001 (0.31)	-.0024 (0.85)	-.005** (2.18)	
Average Population density (people per km^2)				-.001** (3.49)
Illiteracy rate (total adult pop.)	-.001 (0.56)			

% Roads paved	-.003	-.004**	-.003**	-.010**
	(1.17)	(2.27)	(2.06)	(2.51)
Observations	58	64	64	30
R^2	0.71	0.72	0.72	0.77

Table 1b. The Effect of Basic Country Facts on Child Mortality[18]

	(1)	(2)	(3)	(4)
Country is a former colony	-1.25 (0.15)			-1.04 (0.13)
EU dummy	-18.88 (1.31)	-33.04** (2.84)		-20.68 (1.42)
Landlocked	14.22 (1.46)		7.01 (0.51)	14.13 (1.43)
Latin America dummy	-10.15 (0.68)	7.59 (0.70)		-3.22 (0.22)
%Land within 100km of coast or river	-.254 (1.95)		-.872** (5.52)	-.254 (1.93)
Sub-Saharan Africa dummy	103.57** (6.85)	130.65** (14.03)		110.85** (7.51)
South Asia dummy	46.46** (2.25)	48.99** (2.55)		38.37 (1.88)
Southern Hemisphere dummy	-15.37 (1.43)	-21.08** (2.17)		-16.65 (1.54)
%Land in geographical tropics	36.12 (1.84)			
%Land in climatic subtropics	-9.76 (0.44)			17.02 (1.01)
%Land in climatic tropics	-4.24 (0.16)			30.79 (1.59)
Constant term	42.46 (3.92)	39.61 (7.43)	107.17 (10.25)	43.86 (4.02)
Observations	115	141	141	115
R^2	0.74	0.67	0.23	0.73

[18]Data on child mortality rates is measured as the number of deaths of children under 5, per 1,000 live births.

Table 2b. The Effect of Climatic Regions on Child Mortality

%Land in climatic Temperate desert	94.12 (1.76)	%Land in climatic Tropical/subtropical desert	87.26** (2.17)
%Land in climatic Dry temperate region	50.30 (1.09)	%Land in polar region	111.58 (0.81)
%Land in climatic Subtropics	112.8** (2.80)	%Land in climatic Tropics	160.39** (3.96)
%Land in climatic Wet temperate region	24.74 (0.59)	Constant term	-12.96 (0.36)

N = 140; R^2 = 0.36

Table 3b. The Effect of Health Factors on Child Mortality

Health Expenditure per capita (US$)	-.044 (1.35)	Total Health Expenditure (% of GDP)	-4.43 (1.52)
DPT immunization rate (% children under 12)	-1.75** (2.31)	Measles immunization rate (% children under 12)	-.334 (0.39)
Constant term	262.7 (11.37)		

N = 70; R^2 = 0.55

Table 4b. The Effect of Education Factors on Child Mortality

	(1)	(2)	(3)	(4)
Daily newspapers per 1,000 people	-.096 (0.30)			
Government ed. expend. (primary school, per pupil, 1990)	-.195** (2.22)	-.109** (2.06)	-.163** (2.57)	-.003 (0.90)
Government ed. expend. (secondary, per pupil, 1990)	.0177 (0.48)			
Public education spending (% of GDP)		3.52 (0.88)		
Pupil-teacher ratio (primary)		1.87** (3.53)	.972 (1.84)	2.79** (8.46)
Illiteracy rate (Total adult pop.)	.669 (1.32)			
Radios per 1,000 people	-.065 (1.20)			
Tertiary school enrollment (% Gross)	-1.17 (0.98)	-1.62 (1.94)	-2.89** (2.95)	
Televisions per 1,000 people	-.088 (0.48)			
Constant term	139.83 (5.14)	37.05 (1.09)	112.66 (3.61)	-23.97 (1.83)
Observations	32	29	40	79
R^2	0.76	0.74	0.64	0.60

Table 5b. The Effect of Political Variables on Child Mortality

	(1)	(2)
Number of assassinations per million pop. per year	-24.52 (0.37)	
Country a former colony	29.04** (2.33)	24.84** (2.08)
Civil liberties score (Freedom House, 1-7)[19]	29.63** (2.79)	28.34** (2.99)
Timing of independence[20]	21.91** (3.02)	22.28** (3.40)
Political rights score (Freedom House, 1-7)	-12.37 (1.50)	-10.54 (1.40)
Number of revolutions and coups per year	-2.40 (0.10)	7.03 (0.31)
Socialist economic system dummy	-13.76 (0.56)	17.78 (0.88)
Transition economy dummy	-68.75** (2.28)	-95.23** (3.65)
Had an external war (1960-1985)	-16.22 (0.91)	-16.39 (1.01)
Constant term	-13.84 (0.77)	-22.01 (1.32)
Observations	78	91
R^2	0.47	0.47

[19] One being the highest level of civil liberties, and 7 being the least amount of liberty
[20] (0=before 1914, 1=between 1914 and 1945, 2=between 1946 and 1989, 3=after 1989)

Table 6b. The Effect of Aid, Income, and Trade on Child Mortality

	(1)	(2)
Aid per capita (US$)	.358	.418**
	(1.85)	(2.66)
Kilometers to closest major port	.006	.0091**
	(1.59)	(2.96)
GDP per capita (1995)	-.017**	-.013**
	(5.52)	(7.02)
Ratio of real government expenditure to real GDP	113.32	
	(1.50)	
Trade (as % of GDP)	-.567	
	(0.70)	
Constant term	109.05	83.09
	(4.28)	(4.57)
Observations	42	84
R^2	0.65	0.51

Table 7b. The Effect of Population Dynamics on Child Mortality

	(1)	(2)
Coastal population density (people per km^2)	.003 (0.03)	.027 (0.32)
Inland population density (people per km^2)	-.015 (0.23)	
Average population density (people per km^2)	-.053 (0.49)	-.079 (0.95)
Population in 1995	-.037 (0.86)	-.045 (1.19)
% Population within 100km of coast or river	.087 (0.38)	
Rural people per km^2	-.010 (1.62)	-.009 (1.61)
% Population in geographical tropics	83.67** (4.10)	79.65** (4.48)
% Population urban (1995)	-1.75** (5.37)	-1.74** (5.45)
Constant term	148.71 (5.85)	152.99 (6.89)
Observations	80	80
R^2	0.62	0.62

Table 8b. The Effect of Infrastructure on Child Mortality

	(1)	(2)
Daily newspapers per 1,000 people	-.114 (0.40)	
Radios per 1,000 people	.0024 (0.26)	
% Roads paved	-.723** (2.38)	-.666** (2.79)
Telephone mainlines per 1,000 people	.044 (0.16)	
Televisions per 1,000 people	-.238** (2.42)	-.309** (5.11)
Vehicles per 1,000 people	-.418 (1.52)	
Constant term	166.76 (15.22)	148.98 (16.31)
Observations	68	84
R^2	0.54	0.42

Table 9b. Combined Effects on Child Mortality

	(1)	(2)	(3)
Latin America dummy	-5.36 (0.26)	-37.56 (1.81)	
Sub-Saharan Africa dummy	38.09** (2.99)	50.02** (4.18)	
Pupil-teacher ratio (primary)			.485 (1.12)
% Land in climatic tropics	-24.78 (1.87)	-20.29 (1.42)	-6.68 (0.40)
Total health expenditure (as % GDP)	-1.88 (0.89)	-.435 (0.20)	-2.67 (1.01)
Civil liberties score (1-7)	1.05 (0.32)		
Timing of independence	.383 (0.05)	-9.18 (1.29)	5.66 (0.90)
GDP per capita, 1995	-.0038 (1.89)	-.005** (2.50)	
Aid per capita (US$)	.060 (0.49)	.029 (0.21)	
Kilometers to nearest major port	-.001 (0.36)	-.001 (0.38)	.0048 (1.66)
% Population in geographical tropics	48.85** (3.35)		
% Population urban, 1995	.068 (0.22)	.224 (0.77)	-.627** (2.05)
Average Population density (people per km^2)			-.103** (3.07)
Illiteracy rate (total adult pop.)	1.21** (5.98)	1.15** (5.00)	1.61** (5.84)
% Roads paved	-.028 (0.13)	-.380 (1.80)	-.476** (2.23)

Observations	54	57	51
R^2	0.90	0.86	0.81

Table 11. The Likelihood of Fever, Benin (2001)[21]

Literacy[22]	-.063** (4.45)	Age	.001 (1.47)
Received diphtheria vaccination	.086** (3.72)	Have a bednet for sleeping	-.064** (3.46)
Dwelling has screened windows	.152** (2.35)	Urban/rural (0 = rural; 1 = urban)	-.063** (3.10)

N = 3,210; Pseudo R^2 = 0.02

[21] Dependent variable is binary: 1=Respondent reported having a fever in the past 2 weeks.
[22] 0=Can't read at all; 1=Able to read parts of a sentence; 2=Able to read entire sentence

Table 12. The Likelihood of Fever, Brazil

	(1)	(2)
Number of children under 5 in home	.0157 (1.44)	
Type of toilet facility	.006 (1.77)	
Type of toilet facility squared[23]		.0013** (2.97)
Source of drinking water	-.006 (0.76)	
Literacy	-.007 (0.56)	
Highest year of education	-.008 (1.77)	
Age of respondent	-.003** (2.06)	
Observations	3193	3577
Pseudo R^2	.0044	.0021

[23] See the description of "toilet facility" variable in Appendix 2. The squared term was added in an attempt to account for the increasingly worse conditions as one moves from on category of sanitary facility to another.

Table 13. The Likelihood of Fever, Colombia

	(1)	(2)
Number of household members	.003 (0.64)	
Literacy	.043** (2.19)	.031 (1.80)
Highest year of education	.005 (0.60)	
Age of respondent	-.002 (1.43)	
Received diphtheria vaccination		.102** (3.01)
Have bednet for sleeping		.035 (1.37)
Urban/rural (0 = rural; 1 = urban)		-.045 (1.89)
Observations	1,203	1,425
Pseudo R^2	0.005	0.01

APPENDIX 2: DATA DICTIONARY

DEPENDENT VARIABLES

Child mortality: Number of deaths annually in children under 5, measured per 1,000 live births. Compiled from the World Bank online database of country indicators.

Fever prevalence: A question that appears in a few different forms in the DHS and LSMS household surveys. One question asks, "Have you had a fever in the past two weeks?" The responses to this question, then, constitute a dummy, where 1=yes, had a fever. The other form of the question is "Have you had an illness or injury in the past four weeks?" Possible responses included injury only, illness only, both, or don't know. This variable was recast as a dummy, where positive responses include only those people reporting illness.

Malaria intensity: Constructed by Sachs and Gallup, this variable combines geographical information systems (GIS) data on the percent of land subject to malaria with a measure of the proportion of malaria cases that are of the *falciparum* type (the most deadly and resistant strain of the malaria parasite). The malaria intensity index is measured on a 0 to 1 scale, with 1 being the most intense.

BASIC COUNTRY FACTS

Country is a former colony: Basic dummy variable, where 1=yes, country was formerly a colony.

EU dummy: Binary variable for location in the European Union.

Landlocked: Dummy variable equal to 1 if country is landlocked.

%Land in climatic tropics: Percentage of land in a country that experiences a tropical climate, whether within the geographical tropics or not. This is perhaps a better measure when thinking about malaria, as mosquitoes care more about climate than latitude. Measured as a decimal.

%Land in geographical tropics: Percentage of land in a country that lies within the bounds of the geographical tropics—lying between the Tropic of Capricorn and the Tropic of Cancer. Measured as a decimal value.

%Land within 100km of coast or river: The percentage of land in a country that lies within 100 kilometers of the coast or a navigable river. Used as a measure of openness to trade or degree of access to trade. Measured as a percent, not as a decimal.

Latin America dummy: Dummy equal to 1 if country is located in Latin America

South Asia dummy: Dummy for location in South Asia

Southern Hemisphere dummy: Dummy for location in Southern Hemisphere.

Sub-Saharan Africa dummy: Binary variable for location in sub-Saharan Africa.

CLIMATE

%Land in climatic temperate desert, dry temperate region, subtropics, wet temperate region, tropical/subtropical desert, polar region, climatic tropics: Each variable measures percentage of land in a country that experiences each of the various climates, respectively, regardless of geographical location. Measured as a decimal.

DEMOGRAPHICS

Age of respondent: Current age of the person responding to survey questions.

#Children under 5: The number of children under the age of 5 living in the particular household being documented in the survey.

#Household members: Number of people living in the household being questioned in the survey.

Population, 1995: Total population of a country in 1995.

Population density, average: Average number of people per km^2.

Population density, coastal: Average number of people per km^2 along the coast.

Population density, inland: Average number of people per km^2 inland.

%Pop in geographical tropics: Percent of people living in the tropics, as defined geographically (location between the Tropics of Capricorn and Cancer). Measured as a decimal.

%Pop urban (1995): The percent of a country's population living in an urban area in 1995. Expressed as a percent, not a decimal.

%Pop within 100km of coast or river: Percent of people who live within 100 kilometers of the coast or a navigable river. Expressed as a percent, not a decimal.

Rural people: Number of people living in rural area per km^2.

Urban/rural: Dummy equal to 1 if person lives in an urban area.

EDUCATION

Government education expenditure, primary: Real government current educational expenditure per pupil in primary school. Expressed in USD.

Government education expenditure, secondary: Real government current educational expenditure per pupil in secondary school. Expressed in USD.

Highest year of education: Reports the highest year of education attained by the respondent.

Illiteracy rate: Percentage of adults who are illiterate, measured as a percent, not a decimal.

Literacy: Used in the household and individual surveys, this variable takes on a value from 0 to 2, where 0 = cannot read at all, 1 = able to read parts of a sentence, 2 = able to read whole sentence.

Newspapers: Number of daily newspapers available per 1,000 people.

Pupil-teacher ratio: Average number of students per teacher in primary school.

Radios: Number of radios per 1,000 people.

Televisions: Number of televisions per 1,000 people.

Tertiary school enrollment: Enrollment in tertiary school, as a percent of gross enrollment. Reported as a decimal.

HEALTH

Bednet for sleeping: Dummy variable equal to 1 if respondent has a bednet under which to sleep.

Health Expenditure per capita: Government health expenditure per capita, measured in US dollars (USD).

Health Expenditure, total: Total government health expenditure, as a percent of GDP. Measured as a percent, not a decimal.

Immunization rate, DPT: The percent of children under 12 who have received the DPT immunization. Measured as a percent, not a decimal.

Immunization rate, measles: The percent of children under 12 who have received the measles immunization. Measured as a percent, not a decimal.

Received diphtheria vaccination: Dummy variable equal to 1 if the person has received the diphtheria vaccination.

Screened windows: Dummy variable equal to 1 if home or dwelling has screens on the windows.

Source of drinking water: Variable takes on the following values: 1=bottled water, 2=piped into residence, 3=piped into yard, 4=well/spring inside home, 5=well/spring outside home.

Type of toilet facility: Variable takes on the following values: 1=toilet to sewer, 2=toilet to open space, 3=toilet to river/lake, 4=latrine to sewer, 5=latrine not connected, 6=traditional latrine, 7=no facility.

INCOME

Aid per capita: Amount of foreign aid inflows per capita, measured in USD.

GDP per capita: Measured in USD

Kilometers to closest major port: Distance, in kilometers, to the closest major port—used to measure degree of access to trade.

Ratio of real government expenditure to real GDP: Gives total real government expenditure as a percent of real GDP.

Trade: Amount of trade as a percentage of GDP. Expressed as a percent, not a decimal.

INFRASTRUCTURE

Newspapers: Number of daily newspapers available per 1,000 people.

Radios: Number of radios per 1,000 people.

%Roads paved: Percent of roads that are paved in a country. Expressed as a percent, not a decimal.

Telephone lines: Number of telephone mainlines per 1,000 people.

Televisions: Number of televisions per 1,000 people.

Vehicles: Number of vehicles per 1,000 people.

POLITICS

Assassinations: From Robert Barro dataset--reports the number of assassinations per million population per year in a given country.

Civil liberties: From Freedom House "Freedom in the World" annual report. Assesses the extent of civil liberties in a country based on a number of factors (cf. www.freedomhouse. org). Reported on a 1 to 7 scale, with 1 being the highest amount of liberty, and seven being the lowest.

External War: Dummy equal to 1 if the country engaged in an external war anytime between 1960 and 1985.

Former colony: Dummy variable equal to 1 if country was a colony.

Political rights: From Freedom House "Freedom in the World" annual report. Assesses the extent of political rights in a country based on a number of factors (cf. www. freedomhouse.org). Reported on a 1 to 7 scale, with 1 being the most free, and seven being the least free.

Revolutions and coups: Number of revolutions and coups in a country per year, averaged over the period, 1960-84.

Socialist economic system dummy: Binary variable equal to 1 if the country ever operated as a socialist economy between 1950 and 1995.

Timing of independence: A variable which takes on four values, 0-4, based on when the country gained its independence; 0=before 1914, 1=between 1914 and 1945, 2=between 1946 and 1989, 3=after 1989.

Transition economy dummy: Binary equal to 1 for the "transition" economies of Eastern Europe.

APPENDIX 3: COUNTRIES USED IN MACRO ANALYSIS

Afghanistan
Albania
Algeria
American Samoa
Andorra
Angola
Antigua & Barbuda
Antigua and Barbuda
Argentina
Armenia
Aruba
Australia
Austria
Azerbaijan
Bahamas
Bahamas
Bahrain
Bangladesh
Barbados
Belarus
Belgium
Belize
Benin
Bermuda
Bhutan
Bolivia
Bosnia-Herzegovina
Botswana
Brazil
Brunei
Bulgaria
Burkina Faso
Burundi
Cambodia
Cameroon
Canada
Cape Verde
Cayman Islands
Central African Republic
Chad
Channel Islands
Chile
China
Colombia
Comoros
Congo
Congo, Dem. Rep.
Congo, Rep.
Costa Rica
Cote d'Ivoire
Croatia
Cuba
Cyprus
Cyprus, G
Cyprus, T
Czech Republic
Czechoslovakia
Denmark
Djibouti
Dominica
Dominican Republic
East Asia & Pacific
East Timor
Ecuador
Egypt
El Salvador
Equatorial Guinea
Eritrea
Estonia
Ethiopia
Europe & Central Asia
European Monetary Union
Faeroe Islands
Fiji
Finland
France
French Guiana
French Polynesia
Gabon
Gambia
Georgia
Germany
Germany, East
Germany, West
Ghana
Gibraltar
Greece
Greenland
Grenada
Guadeloupe
Guam
Guatemala
Guinea
Guinea-Bissau
Guyana
Haiti
Honduras
Hong Kong
Hungary
Iceland
India
Indonesia
Iran
Iraq
Ireland
Isle Of Man
Israel
Italy
Jamaica
Japan
Jordan
Kazakhstan
Kenya
Kiribati
Korea
Korea, Dem. Rep.
Korea, Rep.
Kuwait
Kyrgyz Republic
Kyrgyzstan
Laos
Latin America & Caribbean
Latvia
Lebanon
Lesotho
Liberia
Libya
Liechtenstein
Lithuania
Luxembourg
Macao
Macedonia
Madagascar
Malawi
Malaysia
Maldives
Mali
Malta
Marshall Islands
Martinique
Mauritania
Mauritius
Mayotte
Mexico
Micronesia
Middle East & North Africa
Middle income
Moldova
Monaco
Mongolia
Montenegro
Morocco
Mozambique
Myanmar
Namibia
Nauru
Nepal
Netherlands
Netherlands Antilles
New Caledonia
New Zealand
Nicaragua
Niger
Nigeria

Northern Mariana Islands
Norway
Oman
Pakistan
Palau
Panama
Papua New Guinea
Paraguay
Peru
Philippines
Poland
Portugal
Puerto Rico
Qatar
Reunion
Romania
Russia
Rwanda
Samoa
San Marino
Sao Tome and Principe
Saudi Arabia
Senegal
Serbia
Seychelles
Sierra Leone
Singapore
Slovak Republic
Slovakia
Slovenia
Solomon Islands
Somalia
South Africa
South Asia
Spain
Sri Lanka
St. Kitts & Nevis
St. Lucia
St. Vincent & Grenadines
Sub-Saharan Africa
Sudan
Suriname
Swaziland
Sweden
Switzerland
Syria
Syrian
Taiwan
Tajikistan
Tanzania
Thailand
Togo
Tonga
Trinidad & Tobago
Tunisia
Turkey
Turkmenistan
Tuvalu
USSR
Uganda
Ukraine
United Arab Emirates
United Kingdom
United States
Upper middle income
Uruguay
Uzbekistan
Vanuatu
Venezuela
Venezuela, RB
Vietnam
Vietnam, N.
Vietnam, S.
Virgin Islands (U.S.)
West Bank and Gaza
Western Sahara
Western Samoa
World
Yemen
Yemen, N.
Yemen, S.
Yugoslavia
Zambia
Zimbabwe

REFERENCES

Barro, Robert and J.W. Lee. (1996). "International Measures of Schooling Years and Schooling Quality," *American Economic Review, Papers and Proceedings*, 86(2), pp. 218-223.

Desowitz, Robert S. *The Malaria Capers (More Tales of Parasites and People, Research and Reality)*. W.W. Norton & Company: New York, 1991.

Easterly, William. *The Elusive Quest for Growth*MIT Press: London, 2001.

Gallup, John Luke, Jeffrey D. Sachs, and Andrew Mellinger (1999). "Geography and Economic Development." *International Regional Science Review* 22(2), August, 179-232. Reprinted from *Annual World Bank Conference on Development Economics 1998*, Boris Pleskovic and Joseph E. Stiglitz (eds.) Washington, DC: The World Bank.

Hanson K.L., Lines J., Goodman C., Jones C., Meek S. *The Economics of Malaria Control*. Report of the London School of Hygiene and Tropical Medicine

Lee, Jong-Wha, Robert J. Barro (2001). "Schooling Quality in a Cross-Section of Countries." *Economica* 68 (272): 465-488.

MARA (Mapping Malaria Risk in Africa). (1998). *Towards an Atlas of Malaria Risk in Africa*. First Technical Report of the MARA/ARMA Collaboration. Durban, South Africa.

Nordin, Stacia. (2002). "Malawi is Not a 'Poor Country'." *Praxis: The Fletcher School Journal of International Development*, (XVII).

Sachs, Jeffrey D. and Warner, Andrew M. (1997). "Sources of slow growth in African economies." *Journal of African Economies*, October, 6(3), 335-76.

WHO (World Health Organization). (2001). *Macroeconomics and Health: Investing in Health for Economic Development*. Report of the Commission on Macroeconomics and Health. Geneva.

USEFUL WEBSITES:

World Bank: www.worldbank.org
World Health Organization: www.who.int
Roll Back Malaria: www.rbm.who.int
United Nations Development Programme: www.undp.org
ReliefWeb: www.reliefweb.int
USAID: www.usaid.gov
MEASURE DHS: www.measuredhs.com
CID Harvard: www.cid.harvard.edu
Centers for Disease Control and Prevention: www.cdc.gov
London School of Hygiene and Tropical Medicine: www.lshtm.ac.uk