## Micro-Economic Approaches to Evaluating the Burden of Malaria

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Micro-Economic Approaches to Evaluating the Burden of Malaria

Pia Malaney

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Abstract

The links between malaria and poverty are both obvious and subtle. While the correlation between the two is apparent, directions and mechanisms of causation are less so, and different methodological approaches to understanding the relationship provide widely divergent perspectives on the impact of the disease. Recent macroeconomic studies have suggested that in highly malarious countries the disease may be responsible for reducing economic growth by up to 1.3 percentage points a year. This methodology, however, functions independently of the chains of causation and cannot shed much light on underlying mechanisms. Micro-economic studies, which aggregate the cost per case to households, find a much smaller impact, generally less than one percent of per capita GDP. The traditional cost-of-illness methodology, which forms the basis of most of these studies, however, was designed to study illnesses that represent a far smaller disease burden. The pandemic nature of malaria presents economic costs that the traditional model is simply not able to capture. The paper explores the difference between the results of the different methodological approaches, examining some of the mechanisms through which malaria can affect long-term economic growth and development, and expands the cost-of-illness methodology to incorporate these effects.

Keywords: Malaria, Economic cost of disease, Burden of disease, Cost of illness

JEL codes: I12, B40

Pia Malaney is a Research Associate at the Center for International Development at Harvard University.
“I have had fever for about three days… Yesterday I took two aspirins. If I could get to the doctor I would. My legs are shivering. I can’t walk… My husband is in the fields, he is also sick. He has been with fever for five days now. He took the medicine given by the health volunteer and went to the fields. He should be resting but rogues will steal our maize if he stays behind to rest. If I was well I could clean the home garden. My plan is to grow cow-peas. Before I do this I must clear the land. The children have to go to school. There is nobody to cook in the afternoons… I can’t move from place to place to do my work. Sitting in one place I can get a little bit done. Our new house isn’t finished, how can we get all this work done? We have to work in the fields, sickness is always present, we have only daughters, and all our work is delayed.”

- Leelawathie, agricultural worker,
  Sri Lanka(161)

A. Introduction: Malaria and the world twice given

The scientist-philosopher Ernst Mach once remarked that ‘the world is given only once’ in an effort to discourage undue effort spent on counterfactuals. In the case of malaria however, the planet can be divided up into regions which are given with and without it; and from the point of view of both public health and economic development, those regions often end up looking like separate worlds.

To take but the most dramatic of examples, it is to malaria that evolutionary biologists often turn when they want to illustrate the Darwinian calculus of life and death. How better can one explain the potentially lethal modification of the genetic code that induces sickle cells, than as a desperate Darwinian defense against the even more deadly ravages of the malaria pandemic? Accordingly, it may be expected that a force strong enough to re-write our DNA, will re-write many of the lives it touches. It is no exaggeration to say that where malaria is present, it can be expected to affect most features of human existence including human mobility, investment choices and even fertility decisions.

We are not powerless to face this force of nature; from simple mosquito coils to investment in the development of a vaccine, there are many avenues that may retard or stop the threat posed by the disease. The economic dimension enters the picture precisely because all of these measures are not equally effective and none is without cost. It is in evaluating the appropriate level of resources towards the control of the disease that the economist is faced with the question “what would the sphere of economic behavior look like in the absence of malaria?” Answering this question provides the first step towards a comprehensive cost benefit analysis.

However, because the effects of the disease can pervade the fabric of human endeavor, it is not surprising that the current state of economic analysis has yet to yield a definitive accounting. To begin with, the state of the art for costing a disease like malaria has not progressed to the point where a dominant paradigm can be said to exist. Rather, there are competing schools of thought, each of which directly addresses some piece of the puzzle at the expense of leaving some other aspect of the problem for a competing methodology.
Recent attempts to assess the economic burden of malaria using cross-country regression analysis have found the disease to be a significant factor in long-term economic growth and development, accounting for between .25 to 1.3 percentage points of economic growth.\textsuperscript{1,2} An impact of this magnitude could mean that over the long run malaria alone could reduce per capita GDP by almost half in highly endemic countries. This is indeed a dramatic result, but assuming that the estimation of the economic burden of the disease using this methodology is indeed accurate, the nature of this technique is that it functions independently of the chains of causation and so cannot shed much light on the underlying mechanisms.

To first approximation, one might expect that the cost of malaria at a national level is an aggregation of the burden it places on individuals and households. Studies that attempt to estimate the burden of the disease on households using a microeconomic approach find that it is, in fact, quite large and especially severe for those in the lowest income brackets. To wit, the costs in terms of prevention, treatment, and the loss of productivity as a result of malaria related morbidity and mortality could represent a significant percentage of the annual income of poor agricultural households. However, when aggregated to provide estimates of the burden of disease on economic growth, the results of these household studies show a much smaller burden than cross-country estimates suggest. This indicates that if cross-country regressions are more accurate, then there are potentially large economic costs that the micro-economic studies are not able to capture, or negative externalities associated with the disease that make its national impact even greater than its impact on individuals and households.

Both the extent of the economic burden of malaria and the mechanisms through which it imposes this burden are relevant for health policy. The primary reason to allocate resources towards malaria prevention and treatment is undoubtedly the significant cost that it represents in human terms. However, in trading off between equally deserving demands on health budgets, and more broadly, development budgets, understanding the extent of the economic impact of an investment in malaria control is important. If malaria alone accounts for more than one percentage point of economic growth, then controlling malaria can lead to a cycle of health and wealth that can have tremendous long-term impact on standards of living in poor malarial countries. Further, the considerable difference between the estimates of the economic burden derived from micro-economic studies and the macro-economic cross-country regressions may provide a valuable insight into the mechanisms through which malaria inhibits development. To the extent that malaria endemicity carries costs that are external to the household as a unit, sufficient private expenditures will not be directed towards its control, and public provision of malaria control strategies will be all the more critical.

To understand the nature of the “malaria gap”, the differences in estimates between micro-economic or “bottom-up” approaches and macro-economic, or “top-down” approaches, we begin by reviewing some of the evidence from studies that use traditional micro-economic methods to assess the burden of the disease at a household level. The most common approach to evaluating the economic burden of malaria has been the
‘human capital method’ (HCM) of cost accounting. To illustrate the HCM, we describe examples of previous studies that use this technique to calculate the cost of malaria in various affected regions. We then discuss some examples of other techniques including the willingness to pay model and the production function approach.

This human capital methodology was evolved in the developed world to evaluate the costs of a range of illnesses such as circulatory disease or respiratory diseases. In much of sub-Saharan Africa, however, malaria represents not merely an illness, but a pandemic. The ubiquity of malaria in some regions leads not only to high prevention and treatment costs and a loss of labor, but also to modifications of social and economic behavior, with potentially serious consequences for economic growth and development. Standard measures of direct and indirect costs generally used to classify the economic burden of disease are simply not designed to capture the full range of these impacts.

Enumerating the range of effects that malaria has on economic and social activity in endemic regions makes it apparent that if the categorical structure of the method is not broadened and adapted, the traditional HCM algorithm will miss effects that were irrelevant or negligible in previous contexts. In section C we suggest modifications of the approach that we believe better implement the spirit of the method in the context of malaria, and describe some of the generalizations and neglected effects that we believe characterize traditional HCM studies. By adopting a more inclusive approach when considering the indirect costs imposed by malarial disease it will be possible to improve micro-economic estimates of the economic burden of malaria, providing a better understanding of the magnitude and causes of this burden.

B. Traditional Micro-Economic Approaches to Calculating the Cost of Malaria

There have been numerous microeconomic studies attempting to assess the economic burden of malaria. As far back as 1919, Carter estimated that malaria cost the United States US$100 million (in 1917 dollars). Since then, many area-specific studies ranging from South and Southeast Asia to Latin America and Africa have attempted to assess the costs imposed by the disease on both households and systems of public health. The results of these studies show considerable variation, in part due to variations in methodology, but also, no doubt, because the burden caused by malarial morbidity and mortality are highly dependent on the endemicity of the disease and the species of parasite involved. While there are different plasmodia that can cause malaria, *Plasmodium falciparum* is far more deadly than other species of the parasite, resulting in more severe morbidity and greater mortality and hence a greater economic burden. Similarly, the nature of the costs associated with the disease also change based on levels of endemicity. In highly endemic areas, mortality occurs primarily amongst infants and young children, while survival to adulthood brings partial immunity. Besides the fact that high infant and child mortality rates seriously diminish quality of life, they potentially have long-term effects on demography and economic growth. However, direct productivity losses are less severe in such an environment than in areas with cyclical fluctuations in the disease, where immunity levels are lower and there is significant malaria related morbidity and mortality at all ages.
The standard approach used by economists to evaluate the micro-economic burden of disease is the cost of illness (COI) methodology. Since it was formalized in the early 1960s, this methodology has become a standard costing technique used in health economics to evaluate the cost of a particular illness to society. COI calculation procedures have bifurcated along two alternate approaches that are often referred to as the human capital method and the willingness-to-pay approach. In the human capital approach, estimations are undertaken as calculations of the cost to society of lost future productivity, discounted to the present. Such calculations attempt a cohort-weighted sum of the future earnings of the premature dead estimated from variations in life expectancy, labor force participation and average salary data at every age. By contrast, in willingness-to-pay calculations, the objective is to deduce (by survey and/or revealed preference) the monetary value that an individual associates to incremental variations in his or her risk of illness or death.

B.1 The Human Capital Methodology (HCM)
The majority of studies attempting to evaluate the burden of malaria on households have used the human capital approach. In this section we examine the HCM, beginning with a description of the methodology, followed by a discussion of several examples of studies based on this approach. Finally we discuss some of the theoretical and practical drawbacks to using the HCM.

B.1.i Description of Methodology
The HCM attempts to account for the direct and indirect costs associated with an illness. Direct costs refer to both private medical care costs and non-private medical care costs. Private medical care costs are private expenditures on prevention, diagnosis, treatment and care of the disease. They include such factors as expenditures on bednets, doctors fees, the cost of anti-malarial drugs, the cost of transportation to medical facilities and necessary support for the patient and, if applicable, an accompanying adult, for the duration of stay at the facility. Non-private medical care costs are public expenditures on both prevention and treatment of the disease. They include expenditures by the government on such factors as vector control, health facilities, education and research.

The indirect costs are the productivity losses associated with the illness. In the human capital methodology they are measured by estimating the income foregone due to both morbidity and mortality. In the case of mortality, foregone income is estimated by calculating the capitalized value of future lifetime earnings that would have been earned by those who died prematurely as a result of the disease, based on projected incomes for different age groups, basic longevity data, and age-specific mortality rates. The indirect cost of morbidity is the value of lost workdays for each person who suffers from malaria and malaria-related illness, and this is also calculated using similar data. Theoretically, these calculations include the lost value of unpaid work done by men and women within the home, though in practice this is seldom assessed. To evaluate the present value of the lost income, future earnings are discounted. Discounting expresses a stream of future money values in their current value terms. It is necessary because a dollar one year from
today is worth less than a dollar today, if only by the real value of interest that would be received on it.

The standard formula for the human capital method of calculating the economic cost of a disease is:

\[ \text{COI} = \text{Private Medical Costs} + \text{Non-Private Medical Costs} + \text{Foregone Income} + \text{Pain and Suffering} \]

While the formula includes the cost of pain and suffering, this is naturally difficult to impute in economic terms. It is therefore generally ignored in studies that use this approach, despite the fact that it represents a real cost. Willingness-to-pay studies implicitly incorporate these costs, as individuals can be expected to take them into account when evaluating how much they would pay in order to reduce their risk of contracting the disease.

B.1.ii Previous Human Capital Studies

We begin by reviewing the results of some of the studies based on the human capital approach. As we will see, the results of these studies have varied quite substantially, based not only on such factors as the endemicity of the disease in the study locale, which actually do impact the cost of the disease, but also the particulars of the way in which the methodology was applied.

One of the earlier studies of cost of illness was a rough estimation of the prevalence and cost of the disease in Pakistan. Khan (1966) calculated that the number of persons affected by malaria in West Pakistan was approximately 4.2 million, out of which 2.5 million were workers. Assuming an annual loss of workdays per person of 10, an average daily wage of Rs.1.30, an average expenditure of Rs.2.50 on medicines and treatment per person, and one days worth of medical services per episode, he estimated the total economic cost of the disease in Pakistan to be Rs. 81 million annually, or approximately 0.75% of GNP. 4

The calculations done by the Khan study were based on very general approximations. There have been further efforts since then that have attempted to gather data with greater care in order to approximate more closely the cost of the disease. In a much larger scale and more detailed study, Shepard and others quantified the economic impact of malaria in case studies in four different countries of Africa, namely Burkina Faso, Chad, the Republic of the Congo, and Rwanda, using different methods to assess the components of the cost of illness formula5. As this study represents perhaps the broadest attempt to apply this approach to date we examine the results in some detail.

In the case of Rwanda, Ettling et al. use national statistics to estimate the costs for the entire country.6 Malaria incidence in this predominantly agricultural economy has risen eight-fold since 1979. The burden of illness, including relatively high mortality rates, is exacerbated by the limited availability of anti-malarial drugs, especially in rural government facilities, where even chloroquine, the most inexpensive and commonly used anti-malarial, is not always available, much less other anti-malarials capable of dealing with resistant strains of the disease.
Totaling costs for personnel, drugs, and supplies, the authors find the non-private medical costs for malaria to range from $2.32 to $4.64 (in 1987 dollars) per case. In addition, they estimate direct costs borne by households to range between $0.39 and $1.64. Based on these estimates they find the direct costs per case of malaria to average $2.58 and the per capita cost to be $0.63. The indirect costs are calculated to include lost productivity to morbidity and mortality. The average rural wage is assumed to be $1.01 per adult per day. Illness time is calculated using actual number of hospital days per adult plus an estimate of three days lost to the illness at home. In addition, it was assumed that one adult day was spent in caretaking for every child episode. However, the significant portion of the indirect costs arise due to foregone income as a result of premature mortality associated with malaria. This was calculated using the Rwandan life expectancy of 49. Future income was discounted at a rate of 5%. In most countries the morbidity associated with malaria is concentrated amongst children, and their future earnings are highly discounted. However, because the rate of adult morbidity is particularly high in Rwanda the indirect cost of malaria is correspondingly large. The total indirect cost in 1989 was estimated to be $9.24 per case and $2.25 per capita.

In a country where the annual per capita income was just over $300, this study estimated the per capita cost of the disease to be $2.88, or approximately 1 percent. The burden was of course much higher in rural areas, where per capita incomes were approximately half the national average. It should be noted, however, that this calculation did not include some of the components specified in the COI methodology, such as public expenditures on vector control, individual expenditures on prevention, transportation costs to health care facilities etc. Projections for 1995 show this cost increasing by a factor of 2.5.

The study in Burkina Faso used a representative household survey in a rural district to calculate direct and indirect costs. The survey provided data on health service utilization and costs, as well as household expenditure such as drugs and transportation. It also collected data on seasonal agricultural production, enabling evaluation of the marginal product of labor during different seasons. The cost per case averaged $5.96, with the per capita cost averaging $1.15. Once again, the largest component was foregone income associated with malaria morbidity, followed by the direct costs incurred by the patient.

The case study in Mayo-Kebbi district of Chad, a primarily agricultural region with savannah type climate and seasonal malaria transmission, used the national medical reporting system to estimate malaria cases. The cost was estimated at $0.60 per capita, representing five days of individual production. The one case study in an urban region, in Brazzaville, Congo found the per capita cost of malaria to be $0.74, or less than one day of individual production.

Based on these studies, Shepard et al. derive estimates of the cost of the costs of malaria for sub-Saharan Africa. They propose that in 1987 a case of malaria cost $9.84, out of which $1.83 was direct costs, and $8.01 was the indirect cost as a result of foregone income associated with malaria morbidity and mortality. The total estimated cost of $0.8
billion represents 0.6% of the gross domestic product (GDP) of sub-Saharan African economies. They predict a rise in this burden to 1% of GDP in 1995. While in part this is based on an assumption of declining per capita GDP, due to rapidly increasing populations, the authors attribute the majority of this rise to the predicted increases in case severity, as well as the cost of treatment based on chloroquine resistance.

As is apparent in the above discussion, the costs of malaria can be particularly burdensome for the poor, as the direct and indirect costs of a single case can often represent a significant percentage of their income. A recent study based on household survey data in Malawi focuses on the costs of malaria for low-income households. This study includes all household costs on prevention and treatment of malaria, as well as foregone income from morbidity. Expenditure on malaria prevention is highly correlated with income in this sample, most likely as a result of the high cost of prevention measures in relation to income levels. The study includes all households with an annual income below $333 (1000 Malawian kwachas), which was almost three fourths of the households surveyed and was believed to be representative of the rural population of Malawi. The mean annual household income was $115. The most frequently used prevention measure, mosquito coils, cost approximately 6.5% of mean annual income for a one month supply, and bednets, which were not easily available, cost between 19% and 28% of mean annual income.

The costs of malaria treatment in case of illness, however, were also significant. The study estimates a malaria rate of 7.5 episodes per child per year, and between 3 and 6 episodes per adult per year. Patients were found to use various sources of treatment ranging from hospitals or health facilities to traditional healers or self-treatment. For each of these sources a cost was tallied, including transportation, treatment, and where applicable, consultation charges. Treatment costs varied depending on the source, but the average annual household expenditure on malaria treatment was estimated at $11.07, representing 9.6% of household income. In addition, malaria morbidity accounted for a loss of 2-3 days of work, either for adult patients or caretakers. There were also days of lower productivity. These costs were estimated at approximately $2.76 per household. Thus while general COI studies find the economic burden of malaria to be lower than the macro-economic results would suggest, the Malawi study indicates that the burden on lower income households is significantly higher, representing, in this case study, 20% of annual household income.

B.1.iii Difficulties with the Human Capital Approach
It is apparent from the various HCM studies described here that despite the apparent specificity of the formula, the methodology in practice differs widely from study to study. This is primarily a result of differences in data collection, as well as an issue of which cost components are included. For example, many studies simply choose not to include foregone income associated with mortality. While such differences in the implementation of the formula lead to inconsistencies that make the interpretation of results difficult, a more fundamental problem with the human capital approach lies in its theoretical foundation.
A significant factor in calculating the economic burden that the disease places on households is the availability of household coping mechanisms. Household survey data have shown conclusively that when an adult is ill within the household, there is a significant amount of labor substitution, with other adults or children taking on parts of their labor burden. This makes it difficult to calculate the true extent to which productivity is lost. Of course, labor substitution generally comes at the cost of labor or leisure time for other members of the family. Implicit in labor substitution practices is often a gender implication, as the burden of labor substitution tends to fall disproportionately upon women. A study in rural Colombia, found that while men bear the greatest disease burden, women bear a greater share of the economic burden imposed by malaria.

Another concern that this observation raises is that the human capital methodology does not take into account the value of leisure or other activities that are not directly priced by the market. While there is some attempt in the formal COI literature to incorporate the value of housework, the practical difficulties of implementing this calculation generally lead to its omission.

Even within the context of a labor market, wages can be a poor measure of productivity, as market failures are known to distort the price of labor. It is often the case that imperfections occur in the labor market so that a person’s earnings differ from the actual value of his/her output or productivity. This is to some extent taken into account in certain COI studies that estimate shadow wages in situations where all productive employment does not take place within the market context.

Even deeper problems exist with the methodology in terms of evaluating what the foregone income calculation actually measures in economic terms, especially in the case of mortality. The human capital approach attempts to evaluate the capitalized value of lost wages associated with an inward shift of the labor supply curve. This would be the difference in the wage bill associated with the old equilibrium, with a greater number of workers, and a new equilibrium that takes into account mortality associated with the disease. However the formula for the calculation uses the original wage ignoring that an inward shift of the supply curve of labor generally causes an increase in wages. The only case in which this approach would be correct as it stands would be if the demand for labor were perfectly elastic; a case which we know empirically to be extremely unusual.

A greater problem arises in the case of a perfectly elastic supply curve, a more plausible assumption in the presence of high unemployment rates. In this extreme case, the reduced labor has no effect whatsoever on productivity, as there is a labor surplus. While there is indeed a significant burden on households who lose an earning member, from the perspective of the national economy the productivity losses may be minimal in an economy with high rates of unemployment.

### B.2 The Willingness-to-Pay Approach
As described above, the theoretical economic model underlying the calculation of indirect costs in human capital approach can be seen to have fundamental flaws. Furthermore, such abstract costs as pain and suffering simply cannot be assessed by this method. It has been argued that the theoretically appropriate way to assess the true cost of malaria on the welfare of the household is to determine the value that it would put on avoiding the disease. If it were possible to elicit a dollar value that the household would pay to prevent the disease, it would presumably capture the burden to the household of treatment costs and lost productivity, as well as the value of the leisure time given up and the cost of the pain and suffering associated with the disease, and other intangible costs which are difficult to price. The willingness-to-pay (WTP) approach, also known as “contingent valuation”, attempts to elicit this value through the use of household surveys.

Theoretically this approach has the advantage that it elicits the full range of personal costs associated with the illness. However, WTP, which was developed originally to assess values for public goods such as the environment, has come under much criticism in the context of “existence” values, which do not derive from private consumption of a good. It has also been pointed out that the results are sometimes subject to personal interpretations of questions and can be biased by respondents’ desire to engage in strategic behavior.

Based on the difficulty of conducting effective WTP studies there are few examples of this approach that can be used to assess the personal costs of malaria. A recent study of the willingness-to-pay to avoid malaria conducted in Tigray, Ethiopia, however, successfully implements this methodology through the use of a carefully constructed survey instrument. The questionnaire, by asking participants how much they would be willing to pay for a hypothetical vaccine that would prevent malaria with certainty for one year, places the issue in a market context, successfully avoiding the issue of existence values. By asking carefully defined, closed-ended questions it also avoids the usual abstract valuations generally required by WTP surveys.

The authors compare the results of the WTP approach to a human capital assessment of the economic burden on households, omitting, of course, the non-private medical costs that are generally included in such studies. They find that amongst this sample of primarily agricultural households with a mean income of $220, the value of preventing malaria with vaccines was approximately $36, or 16%. Respondents indicated that vaccines would be primarily directed towards adults, an indication that the principal benefit was seen to be prevention of lost productivity. The WTP results are on average two to three times the expected cost of illness estimated by the authors in the same sample. This is a strong indication that standard COI studies which use the human capital approach grossly underestimate the economic burden of the disease on households.

B.3 The Production Function Approach
Another approach to eliciting the productivity costs of the disease is the production function approach. COI studies estimate lost productivity based on days of work missed. However, patients often cannot afford to fully recover from a malaria episode before returning to work. Furthermore, in highly endemic regions a high percentage of the
population is chronically infected, and parasitemia persists even when individuals are non-symptomatic. Therefore even though individuals are working, productive capacity can be expected to be lower under such circumstances. A study in southern India, estimated that amongst households whose members suffered with malaria, cropland cleared was only 40% of that amongst households that did not. This suggests a significantly higher burden than is indicated by COI results.

A method that enables an assessment of general loss of productivity is to estimate a production function and, using regression analysis, to evaluate the loss in output with respect to prevalence of illness. There are, however, few studies that have used this technique to evaluate the cost of malaria, in part because of data issues, and in part because the model itself is difficult to specify. Audibert (1986) does attempt to estimate such a model using data on rice production in an agricultural development project in the Cameroon to study the impact of malaria and schistomiasis on output. Surprisingly, while the results indicate that schistomiasis has a considerable negative effect, they do not find any significant impact of malaria prevalence on rice output.

The three different approaches discussed above give a broad range of results for the economic costs of malaria. Leaving aside fundamental data problems each of these approaches is picking up only certain costs of the illness. In the case of the human capital approach, it may miss costs that are not easily estimated numerically. In the case of the WTP approach only household costs are incorporated. The production function approach makes no attempt to include direct costs of the disease. There are, moreover, other costs that may represent a significant burden at a national level that none of these approaches consider. We attempt here to develop a more comprehensive framework within which to consider the full extent of the economic costs imposed by malaria, using the HCM approach as a basis for expansion.

C. Costing a Pandemic

The HCM was developed to comprehensively assess the economic burden imposed by an illness. The pandemic nature of malaria, however, entails costs that are considerably broader and more far-reaching than this method was designed to incorporate. The intention of HCM is to enumerate mutually exclusive categories of costs that are both computable and exhaustive. While this approach appears to be the correct one at an essentially tautological level, the basic HCM formula strains under the weight of a disease that affects entire societies on an effectively permanent basis. The standard implementation of the HCM meets the criteria of being comprised of mutually exclusive categories, but it nevertheless fails to be exhaustive in this context. In order to do a more comprehensive accounting of the costs of malaria, it therefore appears necessary to broaden our implementation of the human capital approach.

We present here a modification of the terms in the standard formula to allow us to think more comprehensively about the costs associated with a pandemic such as malaria. Consider the following generalization of the HCM:
While there is a price to be paid for this modification, in that it initially introduces some ambiguity with respect to mutual exclusivity of the terms, it allows for a framework within which to account more fully for the costs of malaria at a household level.

The first two terms, private medical costs and non-private medical costs, are captured effectively by the HCM. The pandemic nature of malaria in endemic areas however clearly entails indirect costs that are much broader than simply lost wages. The ubiquity of the disease in certain regions leads to a modification of social and economic behavior with serious consequences for economic growth. The above formula attempts to capture two broad categories of costs that are specific to pandemics, which malaria can be seen to exact in the regions where it is prevalent.

The fourth term, ‘risk related behavior modification’ refers to the effects caused by modification of social and economic decisions in response to the risk of contracting the illness in highly endemic areas. It has been widely observed in the descriptive literature that decision making in such diverse areas as crop choice, trade, investment, and fertility are all affected by the risk of the disease, with a potentially significant negative effect on economic productivity and growth. For example, lack of acquired immunity may inhibit local traders from travel within malarial regions, limiting the development of markets that form the building blocks of economic growth. Similarly fear of contracting the disease through travel to the region may discourage foreign trade and investment.

The fifth term, ‘investment loss’, refers to the effects of the disease on the long-term economic growth process through its impact on the accumulation of human and physical capital. High savings and investments in physical and human capital have formed the engine of growth in many of today’s most advanced and rapidly developing economies. The drain on family resources through both the direct and indirect costs of the disease can limit the ability of households to save and invest in physical and financial capital. Moreover it limits the funds that they have available to invest in the human capital of their children through education. Human capital accumulation is also affected directly, as both school attendance and performance are affected by malaria.

The sixth term, the ‘non-economic personal burden’, includes the cost of pain and suffering as well as other effects such as the loss of leisure and the gender implications of asymmetric household coping mechanisms for malaria.

While the terms included in this framework may be at times difficult to calculate explicitly and may need to be carefully specified so as to retain the property of being cleanly mutually exclusive, the broader framework allows us to think more comprehensively about the costs of the disease. We now describe in more detail some of the factors that would be included in this framework.
C.1 Risk Related Behavior Modification
Where the likelihood of contracting the disease is high, social and economic decisions are often modified to incorporate the risk of illness. In this section we explore some of the impacts of behavior modification in response to malaria risk.

C.1.i Land Use
Amongst subsistence level households, where the tolerance of risk is very low, the threat of malaria can encourage households to adapt their land use decisions to accommodate the risk. For example, in an in-depth case study of the malaria burden in Paraguay, Conly (1975) finds that farmers at high risk of contracting the illness were less likely to plant cash crops such as tobacco and cotton, instead relying on subsistence crops such as corn and cassava. The cash crops, though more profitable, required greater labor input, with harvests suffering greatly if not tended in time. Subsistence crops, on the other hand, were more resistant and hence did not need as much attention at specific times. The loss of efficiency in the harvesting of tobacco crops among families highly affected by malaria was reported to be 33%. For corn it was 15%, while for cassava, which requires little by way of timeliness, it was essentially insignificant. Though the value of cash crops was considerably higher, poor families could not withstand the risk of large losses if they were afflicted by malaria at an inopportune time. Malaria prevalence therefore modified land use decisions simply based on the risk of contracting the disease, resulting in lowered economic productivity.

C.1.ii Migration and Population Mobility
The risk of malaria acquisition has been documented to have a significant impact on population mobility and settlement of new lands, with consequent impacts on economic growth and development. While adults living in highly endemic areas generally develop partial immunity to the malaria parasite, making them less susceptible to malaria morbidity and mortality, migrants from non-malarial regions do not carry the same immunity. Moreover, the acquired partial immunity of adults is dissipated by the absence from a malarious environment over the course of a few years, for example during a period of schooling or a job assignment away from the malarious region. This can result in high disease morbidity and mortality upon return, or it can depress the extent of short-term migration for schooling or temporary job opportunities in other locations. The costs of migration may also have implications for social equity, as migrants tend to be from the lowest socio-economic brackets, and therefore least able to bear the economic costs of the disease.

As far back as 1936, Sinton described the effect of the disease in preventing expansion into new territories in India, such as the Terrai region of Uttar Pradesh and the sugar plantations in Bengal and Assam. The population pressures in the Indian sub-continent eventually forced it to overcome these challenges. However the problem is still found in other regions of the world, as the prevalence of malaria prevents the colonization of certain areas. While there may indeed be environmental benefits to limiting land development, malaria removes the option of land preservation from human choice, presumably with less efficient outcomes. In the case of Brazil, despite government efforts to colonize and settle frontier areas, Sawyer (1993) describes the difficulty in
attracting agricultural settlers because of the prevalence of malaria and other endemic diseases:

“An explosion of the prevalence of malaria, partially caused by the opening of a major road through the Amazon rain forest, and the subsequent influx of non-immunes into the area, has made agricultural settlement physically and financially expensive both for the agricultural settlers and for the government. The disease can be so physically debilitating that it undermines family farm production and hence the economic benefits of permanent settlement. Potential settlers quickly recalculate the costs and benefits of farm production in the presence of chronic exposure to the disease…. Over the long run agricultural settlement does not take place, and the population remains essentially without vested interest in creating a permanent social infrastructure and continues to be unstable and mobile.”

By limiting the movement of labor to regions where it is most productive malaria can interfere with skill matching and generally inhibit maximization of worker productivity. Furthermore, to the extent that greater trade and commercialization exposes individuals to the disease it will reduce incentives to expand markets, a factor that can hinder economic development in the long run.

C.1.iii Demographic Impacts
A disease like malaria, which kills between one and two million people a year, cannot but have a significant demographic impact. Further, these impacts are highly concentrated, as 90% of malaria incidence is concentrated in the African continent. However, malaria does more than just increase death rates. In highly endemic areas malaria mortality is concentrated among children under the age of five, and the disease therefore has effects on the age structure of these populations. It also potentially has long-term effects in terms of the timing and nature of the demographic transition in countries where it is prevalent.

The critical role that malaria plays in the demography of highly endemic countries has been emphasized by improvements in life expectancy and reductions in the crude death rates in regions with successful malaria control policies. A particularly good example is the case of post World War II Sri Lanka. The climate across different regions of this South Asian island varies considerably, and this was reflected in malaria prevalence. Before 1945 certain areas of the country were highly endemic, while in other areas endemicity rates were significantly lower. There was correspondingly high variation in death rates across districts. In 1945, soon after commercial DDT became widely available, there was an intensive effort at malaria control in Sri Lanka. The result was an almost immediate decline in the inter-district variation in death rates across the country as mortality fell dramatically in highly endemic areas. The malaria mortality rate per million declined from 1,873 in 1946 to 252 in 1950. Death rates as a whole continued to decline across the country, but up to 23% of the decline in national death rates in the post-war period has been attributed to the control of malaria.

The significance of the disease in determining death rates has led some researchers to speculate that successes in malaria control could be responsible for triggering a population explosion in developing countries. Not only do death rates decline, but
evidence from Sri Lanka also shows that malaria control may initially be associated with increased fertility, most likely as a result of a decrease in the rate of malaria induced abortions. Barlow (1968) claims that the eradication effort in Sri Lanka initially had positive effects on household income through declines in morbidity. In the long run, though, he argues that the negative effects in population growth associated with control of the disease outstripped the economic benefits, as increasing population placed greater demands on the government for social service expenditures, eating into resources for public infrastructure development.

While the short-term effect of controlling malaria is certainly to reduce death rates and increase population size, the long-term effects of such changes and their impact on economic growth are not straightforward. To the extent that malaria control disproportionately benefits young children, the decline in death rates in this age bracket can be initially expected to swell the cohort. This will be exacerbated if fertility also increases as a result of controls. However the standard demographic pattern experienced by populations in modern times is the shift from high mortality and high fertility rates to low mortality and low fertility rates – the so-called demographic transition. A decline in infant mortality rates is invariably the first step in this transition. While fertility rates are generally slower to decline, the mortality decline is almost always a prerequisite to bringing down fertility rates.

There are several hypotheses as to the reason for this link between fertility and mortality. One explanation is that parents have additional children to replace the ones that they lose. This “child-replacement” strategy is supported by the biological response that makes a lactating mother considerably less likely to conceive, and this natural birth control is interrupted with the loss of a child. Another hypothesis, known as the “child-survival hypothesis,” is that parents base their fertility decisions on a desire for a certain number of surviving children (for example to guarantee at least one surviving male heir, or one surviving child into the old age of the parents). In this theory, risk-averse households raise fertility by even more than expected mortality, in order to ensure a sufficiently high likelihood of the desired number of children surviving. By this argument, reducing infant mortality and therefore limiting the need to plan around the high risk of losing children can be expected to lead to a reduction in fertility by an even greater amount. The impact on population growth and age structure depends on the elasticity of response of fertility to changes in mortality. In a study of pre-industrial Europe, Galloway (1988) finds that a 1% increase in infant mortality could lead to between 0.5 and 1.55% increase in fertility.

The “child-survival” theory predicts that a high burden of malaria will lead to a disproportionately high fertility rate and an overall high population growth rate in highly malarious regions. These predictions are supported by cross-country evidence showing very high population growth rates and high fertility rates in high transmission regions, though the direct causal linkages from disease to increased fertility to rapid population growth are yet to be proved.
The link between population growth and economic growth has also been an issue of long-standing debate. However, there is increasing evidence that the age-structure effects that accompany the demographic transition could potentially boost economic growth. At the simplest level, if couples are following a replacement strategy, at any given time there will be many more young children in the population than are expected to survive into adulthood. In the absence of malaria-related mortality couples could have fewer children, and the per-capita GDP would be higher as a result of a decline in the so-called dependency ratio: the ratio of dependents to workers in the economy. The long-term effects of this shift in age-structure can be significant, as working age parents with fewer children to support can afford to save and invest more both in physical capital and in human capital through the education of their children.\(^{23}\)

An increase in the incentive to invest in children’s education is a direct consequence of declining infant mortality. The so-called quantity-quality trade-off posits that as the odds of losing children declines, couples will shift towards investing in the health and education of a smaller number of children rather than spreading their investments thinly over a larger number of children with little advance indication which offspring will survive to adulthood.

Another direct, if seldom included loss, is the opportunity cost of time and resources invested in infants who do not survive. The disease burden of malaria in endemic areas falls predominantly on children, and approximately one million children under five are lost to the disease every year. Aside from the human cost of this loss, the economic value of resources invested in these children can be significant. Reher (1995) estimated the number of hours parents spend in child-rearing for every year of a child’s life based on generalized assumptions.\(^{24}\) He then calculated the productive time “lost” based on infant and child mortality. In high mortality societies this number was substantial. For example, in Senegal, between 1974 and 1977 he found an average of 1,988 hours of “wasted” parental time per couple. Assuming a ten-hour workday this translates to almost 200 days of work. In the case of Bangladesh between 1971 and 1975 the average was 1,420 hours. Though these are obviously very rough estimates they do indicate that the costs of a high mortality-high fertility environment can be considerable.

A high mortality-high fertility environment imposes subtler though no less significant costs through its effects on the productivity of women. When women have very high fertility rates, parents may choose to invest less in the education of their daughters, knowing that they are likely to spend a significant portion of their working years involved in child-rearing activities rather than in the labor force where they would reap the economic returns to education. Moreover, while the hours they spend caring for a young child may not represent a majority of their workday, women will undoubtedly be limited in their employment choices by the need to be available to the child, with a resulting loss in work opportunities and job experience. Over the long-term such factors can have a sizeable impact on economic growth and productivity.
C.2 Loss in Investment
The heavy cost burden imposed by malaria on households has potentially significant macro-economic consequences as it interferes with a family’s ability to save and invest in both human and physical capital. Investments in education and physical capital have proved to be the engine of growth in many of the rapid growth economies, such as the so-called “tigers” of East Asia. The direct economic burden that malaria places on households can therefore have long-term consequences for economic growth.

C.2.i Saving
The direct costs of prevention and treatment of the disease eat into the disposable incomes of poor families, as do the costs of lost productivity. Nur (1993) documents the negative impact of malaria on household savings as families are forced to hire labor to compensate for days lost to morbidity. While economic models suggest that increased risk of illness could, in fact, increase savings if families were trying to protect themselves from vulnerability to economic shocks by building a buffer, there is little evidence to support this idea in the poor, rural households that have been studied.

The long-term demographic impacts of malaria discussed in the last section also potentially affect savings rates. If reduced malaria-related infant and child mortality does, in fact, bring down fertility rates, then the resulting decline in the dependency ratio could lead to a higher savings rate. It has been argued that families with lower dependency ratios, with fewer children to feed and clothe, are more capable of saving and investing, not just in physical capital or capital markets, but also in the human capital of their children through education.

C.2.ii Schooling
The disproportionate impact of the disease on young children in highly endemic areas affects both school attendance and performance, and can thereby reduce the returns to investment in education. While morbidity is highly concentrated in preschool children, school age children also bear some impact. The most obvious manifestation of the problem is the loss of schooldays to illness. Leighton and Foster (1993) estimate that in Kenya, primary school students miss 11 percent of school days per year because of malaria, and 4.3 percent of secondary school days. In the case of Nigeria, they find that between 2 to 6 percent of the school year is lost. A study in the Solomon Islands finds that the average case of malaria in children between 7 and 13 years of age causes a loss of 5.3 days of school. Yet another study in Kenya finds 13-50% of medically related absences are attributable to malaria. The impact of school absenteeism goes beyond the actual number of days lost, as high rates of absenteeism are found to result in higher repetition and dropout rates.

A more subtle but far more insidious effect of the disease is its impact on cognitive development and learning ability. Although there is some debate about the direct relationship between malaria and mental functioning, a number of channels have been identified through which malaria can affect cognitive abilities. Studies have found that parasitaemic children perform worse than non-parasitaemic children in tests of fine motor functions. At a broader level, the negative effects of malaria on the nutritional status of
children can impair brain development.\textsuperscript{30,31,32,33} The cognitive effects of malaria can begin at an even earlier stage by affecting fetal development. Pregnant women are particularly likely to be infected by malaria as a result of diminished immunity, and malaria-related anaemia of the mother is related to low birthweight among babies. This is a risk factor for neurosensory, cognitive and behavioural development of children. It has been found that compared with normal birthweight babies, low birthweight babies are two to four times more likely to experience failure in school.

C.3 Links between Malaria and Other Illnesses

There is substantial evidence of links between malaria and a number of other illnesses. To the extent that malaria is a contributing factor for other illness it is necessary to attribute to it a share of the entire range of direct and indirect costs associated with those illnesses. Acute and chronic malaria infections can alter the immune system and increase vulnerability to other infections and response to vaccines. Malaria is also associated with hyperreactive malarial splenomegaly, chronic renal damage and the nephrotic syndrome, and Burkitt’s lymphoma. It has been found to inhibit appetite and growth in children and infants\textsuperscript{34, 35}. Furthermore, acute malarial infection can have chronic health consequences: cerebral malaria has been found to cause long-term neurological damage in a significant percent of those who do survive. Perhaps most tellingly, the presence of malaria has represented such a significant disease burden through the ages that it has led to a potentially deadly genetic modification causing approximately 130,000 infants in Africa to be born each year with sickle cell disease.

A particularly burdensome consequence of malaria in endemic regions is its role as a primary causal factor for anemia\textsuperscript{36, 37}. Direct evidence of the negative physical effects of anemia is available in the numerous studies showing that anemia lowers worker productivity. For example, Scholz et al. (1997) found a significant correlation between work output and hemoglobin amongst female jute-factory workers in Indonesia\textsuperscript{38}. Anemic women were found to produce an average of 5.3\% less in the factory, and performed an average of 6.5 hours less of housework a week. A study of rubber tappers and weeders in Indonesia also found that earnings, which were based on output, were strongly correlated with hemoglobin levels, and treatment with elemental iron greatly increased work output among subjects\textsuperscript{39}.

Cases of severe malaria often result in severe anemia, especially in young children. This can be fatal, and survival frequently requires blood transfusions. Blood screening systems are severely underdeveloped in many sub-Saharan African countries and transfusions are therefore a direct pathway for the transmission of bloodborne pathogens such as hepatitis B, hepatitis C, CMV, parvovirus and others. An increasingly deadly consequence is the transmission of HIV through infected blood supplies. Ten to fifteen percent of total HIV transmission and up to twenty five percent of pediatric transmission in sub-Saharan Africa is a result of blood transfusions, primarily for the treatment of severe malaria and sickle cell anemia.\textsuperscript{40, 41} The economic burden of HIV is thought to be extremely high, and the role that malaria plays in increasing HIV seroprevalence rates represents a particularly costly consequence, not just in human but also in economic terms.
Other forms of treatment for malaria can also have negative consequences. Injections are often the preferred form of administration of drugs for malarial patients, exposing them to infections caused by poorly sterilized equipment. Furthermore, the pandemic nature of the disease causes many fevers to be misdiagnosed as malaria. Not only does this expose patients unnecessarily to the infection risks and the toxicity of malaria drugs, it also interferes with them receiving treatment for their true ailment(s).

D. Conclusion

The standard micro-economic approach to evaluating the economic burden of malaria, the cost of illness methodology, finds that malaria can impose a significant cost on households and governments. However, these costs, when aggregated, do not begin to approach the magnitude of the costs indicated by the cross-country regression analysis described elsewhere in this volume. That the COI methodology can be expected to understate the true extent of the economic burden imposed by the disease is not difficult to see. The pandemic nature of malaria in some parts of the world creates broad costs that this approach is simply not designed to recognize, and these costs have potentially large-scale impacts on economic growth over the long run.

The basic approach of the human capital method is to seek to identify all of the various pathways by which the disease imposes costs. Other methods such as cross-country regression analysis, willingness-to-pay, and the production function approach use inclusive approaches to bypass the problem of having to understand the exact casual links by which malaria affects the afflicted. The divergence of these approaches would suggest that the total estimated costs returned by each of these approaches will continue to be highly dependent on the choice of methodology.

Given this perspective we may well ask if it is possible to bridge the gap that exists between the studies built on these fundamentally different methodological foundations. We have tried to illustrate something of this perspective here. The human capital method can and should have a more inclusive notion of indirect costs in place of the narrowly defined forgone income term familiar from traditional HCM calculations. The terms should be structured to include such effects as the loss of investment and the modification of behavior in response to the high risk of malarial infection. By adopting a more inclusive approach when considering the indirect costs imposed by malarial disease it will be possible to better aggregate ‘from the bottom up’ the range of costs associated with the disease. Conversely, if the addition of such terms fails to approach the level of cost predicted by cross-country regressions or willingness-to-pay studies, it may then be profitable to see whether those studies are not conflating the cost of malaria with other factors with which malaria may be correlated. Thus if both perspectives take the opportunity to tutor their counterpart through successive approximation, there is reason to believe that the gap should decrease through a process of convergence and allow us a more comprehensive picture of malaria and its varied effects.
41 Ryder RW. Difficulties associated with providing an HIV-free blood supply in tropical Africa. Aids. 6(11):1395-7, 1992 Nov