

THE ECONOMICS OF MALARIA CONTROL

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Ideally, in devising and assessing policies to control disease, the rules and reasoning of economics should be combined with comprehensive epidemiological information to arrive at the best decisions. Simple economic concepts can be of great practical assistance to policymakers in disease control. This article describes the economic principles to be applied and the kind of information needed to make informed choices about the options for controlling malaria. In this context, the article surveys the research on the costs that malaria imposes on people and economies, discusses how to assess the costs and effects of interventions used to combat the problem, and identifies the conceptual difficulties and gaps in information that must be bridged before the marriage of the two disciplines can be effectively consummated.

Malaria strikes an estimated 100 million or more people in the developing world each year, killing 1 to 2 million of them. It is one of the biggest killers of children in Sub-Saharan Africa, where 80 percent of the cases and an estimated 90 percent of the parasite infections occur. A mosquito-borne disease, malaria has many diverse forms. The methods suitable for its control are correspondingly diverse.

At the end of World War II eradication of malaria was considered attainable; in 1955 the World Health Assembly made worldwide eradication the goal of its control programs. The effectiveness of DDT in mosquito control and of drug therapies such as chloroquine made such optimism tenable. Already malaria had been reduced in some areas—although how much of the reduction was attributable to control and how much to economic development and the loss of mosquito breeding grounds to human settlements is unclear. In any

case, the initial optimism had to give way to the growing realization that continued surveillance and control efforts, essential to maintaining and building on the earlier successes, were extremely hard to sustain—as attested by resurgence of the disease in many places where progress had been made. More recent tactics have aimed to control rather than to eradicate the disease.

In many places around the globe, the problem has actually worsened. The malaria parasite has progressively developed resistance to chloroquine, the principal drug for combating the disease. The need to replace chloroquine, a cheap and effective treatment for all forms of malaria, with more expensive and more dangerous drugs has dealt a heavy blow to control efforts. Meanwhile, the mosquitoes have been developing resistance to the main insecticides used for their control. And, at the same time, the deadliest of the four strains of the malaria parasite that cause disease in humans (*Plasmodium falciparum*) has been growing relative to the others (*P. ovale*, *P. malariae*, and *P. vivax*). Little wonder that a recent report (Oaks and others 1991) from the Institute of Medicine of the U.S. National Academy of Sciences begins: “The outlook for malaria control is grim.” As one eminent malariologist (Bradley 1991) has described it, the historical development of thinking about malaria can be characterized by decade: the 1950s was the decade of eradication in its attack phase, the 1960s was that of eradication in its consolidation phase, the 1970s saw a resurgence of the disease, and the 1980s was a decade of chaos—though Bradley does allow the 1990s to be the decade of hope.

Current hopes are centered on the possibility of developing a vaccine. Whether such a vaccine can maintain its viability and long-term effectiveness in the face of the parasite’s capacity for developing resistance remains conjectural. In the meantime, policymakers still need to make choices on the basis of the existing knowledge about malaria control.

Integrating Economics with Epidemiology

The potential for integrating economic and epidemiological reasoning in the formulation of policy for malaria control is great and largely untapped. Whereas the epidemiology of the disease is necessary to define the bounds of the possible, the bread and butter of economics is the making of choices among the different possibilities—either in describing how people (as consumers or as producers of goods and services) actually make choices or in prescribing how governments should make them.

The Ideal: Policymaking with Complete Information

Ideally, decisionmakers applying economic reasoning to the policy choices entailed in controlling malaria would have at their disposal precise information of the following kind. For each available policy instrument (such as building clinics

or organizing spraying teams), they would know what effect different levels of use of the instrument would have on the outcome—preferably measured in some common unit of account, like money. For the same instruments, they would then know how much it would cost, in the same unit of measurement, to operate this activity at different levels (the number of clinics or teams). The rule for the decision is then easy: expand the use of each policy instrument as long as the benefits received from the expansion outweigh the costs. These benefits and costs from the expansion may be termed the marginal benefits and costs. At some point, the marginal benefits and costs will be about equal, and this balance defines the right level for the instrument. Stopping short of that level leaves some benefits (net of their costs) unexploited. Going too far entails costs that are too high relative to the benefits received. If the activity involved is discrete—that is, if it is an all-or-nothing proposition or an investment that entails a particular package of inputs—then this rule translates into: Do it if and only if the benefits outweigh the costs. Most cost-benefit analyses are done on such discrete packages of inputs and outputs. In the ideal world, the information concerning each of these components would be available and used according to these principles to evaluate the available policies.

It follows that a central criterion in selecting among alternative strategies is that choices should be based not on the size of the problem, but on the effects that policies have on the outcome. That malaria affects so many people in the world is not on its own sufficient to make it an important priority for policy: what matters is whether something can be done about it. The appendix to this article gives a numerical illustration of this point. (One exception needs to be noted to the argument that it is the marginal effect, not absolute burden, that matters in setting priorities. The criterion does not apply when the instrument in question is pure research, say, on new drugs. Here the project's success is speculative in terms both of costs and outcome, and one might as well go for the larger targets. The burden of the disease defines at least the upper bound of the project's value.)

At the different levels in the hierarchy of decisions to be made, the sets of problems to be solved may look quite different from one another. At the highest level of government, the value of resources put into health must be assessed against those allocated to other sectors; within the health sector, a ministry may need to assess the problem of malaria versus other diseases; within a malaria control program, a manager faces the choice of dividing resources between alternative control methods such as vector (mosquito) control and case management (the treatment of the disease once contracted). In the ideal world of adequate epidemiological information and common units of account just described, the procedure for making choices among different strategies should be equally applicable to all these types of decisions. In practice applying the procedure is not so simple.

The Reality: Conceptual Difficulties and Incomplete Information

The two principal components of the analytical procedure described above—defining the policy and defining the relationships among policy instru-

ments, objectives, and costs—are, in the real world, bedevilled by problems, both conceptual and practical.

DEFINING THE POLICY OPTIONS. Defining the available policy instrument—that is, determining what is actually under the control of the policymaker—is not as easy as it may seem. Epidemiological research typically identifies risk factors associated with the disease. These risk factors are not, themselves, necessarily under the control of the decisionmaker. Take, for example, vector capacity—the number of infected bites a person receives in a given period of time, which itself is a function of the relative populations of mosquitoes and people, the feeding habits of the mosquito, and the personal measures people take to protect themselves. The effect of vector capacity on the incidence of disease may be identified. But neither vector capacity nor any of its components are directly controllable by governments. When, for example, a government decides to spray houses for mosquitoes, it may specify the number or proportion of houses to be sprayed, which merely helps determine the death rate of mosquitoes. Strictly speaking, the only aspect of policy implementation it directly controls is the hiring and instruction of workers. Unless it has an administrative or monitoring capacity that few organizations possess, the government cannot control whether those workers spray houses successfully. Each of these links helps to determine the actual functional relationship of the policy to the outcome. In drug therapy, the technical effectiveness of a drug may be identified, but the degree to which it affects the disease depends on how many people show up for treatment and how well they comply with prescriptions. The relevant policy instrument here is more likely to be information, education, communication, active detection of malarial infection, or the pricing of government health services, than simply the choice of drugs.

Vector control operations usually entail well-defined investments that are almost always made by the public, rather than the private, sector. Such operations are easily put into the framework described above. Identifying the government's role and policy levers for case management is more complex, however, because these differ according to the structure of different health care systems. The policy instruments effective in a system in which most health care is provided within the family or by the private sector through traditional healers, private doctors and nurses, or pharmacists will differ from those suitable when all services are provided in public primary health facilities or malaria clinics. The instruments in the former might be taxes or subsidies for different drugs, or campaigns to inform private providers or the public; for the latter, facility protocols could directly control the types and dosages of drugs used. Evaluating the benefits of providing free drug therapy, for example, would require knowing what substitutes are available for treatment sought outside the public sector; as a service, drug therapy is a nontraded good (internationally) and *net* additional people treated depends on the extent of substitution from the private sector (or nongovernmental organizations). The policy may look

very different if substitution is high—less a health intervention and more a transfer from taxpayers to clinic users. A policy that merely switches the treatment venue from private to public clinics may not treat any more people. But this is a progressive policy if the average taxpayer is better off than the average clinic user. In many places in Africa, however, taxes are based on agricultural exports and are therefore frequently regressive, whereas clinics may be disproportionately available in urban areas and used by the relatively wealthy.

FUNCTIONAL RELATIONSHIPS BETWEEN INSTRUMENTS AND OUTCOMES. The conceptual problem involved in evaluating an instrument in terms of expected results is the difficulty of defining an outcome that can be compared to the cost of inputs. Because of basic problems associated with placing a monetary value on lives saved, outcomes—especially if some are in terms of mortality and others in morbidity—are difficult to compare. If results can be fully valued in monetary units, cost-benefit analysis can be applied, and investments in health can be directly compared to those for, say, road building. Short of this, intermediate outputs can be defined and compared across projects. In health, lives saved is a popular measure of outcomes, as is “discounted quality-adjusted life years.”¹ That measure is used, for example, in a forthcoming World Bank study of disease control priorities in developing countries (Jamison and others forthcoming).

Once a unit of output is defined, one needs to know what is achieved by each dollar spent or program pursued. Complete information on this score is hard to come by for three reasons. First, although a policy may be directed toward one specific aim, its effects may be felt in other areas. Vector control aimed at malaria could well affect the transmission of other diseases or contribute to environmental degradation. Changes in water management practices to control mosquitoes can affect agriculture. More accurate diagnostic techniques for detecting malaria also improve the information useful for the treatment of other diseases. These external effects, for good or ill, should be part of the evaluation.

Second, the effectiveness of a policy depends on the extent to which it is used. The degree of use can increase or reduce the cost of each life saved. If a new clinic is to be built, the costs of the investment may be spread over a large number of potential users and so will decline over some range. Alternatively, the effectiveness of an information campaign (on, say, personal protection) may fall as more and more is spent to educate hard-to-reach people.

The appendix gives five examples of this point and a sense of how it affects policy decisions. A full analysis would require information on the complete relationship among different levels of the use of a policy instrument and its effect on the disease. The key point is that it is necessary to know the marginal benefit of an activity at each level of use to compare to its marginal cost. The crucial contribution of epidemiology clearly is to identify the link between risk factor and incidence of disease. But epidemiology does not necessarily reveal the other link, between the risk factors and policy variables—taxes, subsidies, govern-

ment hiring, and organization rules. The role of organizational structures, either local or national, can be essential in gauging the effectiveness of a policy.

The Current State of Knowledge

Research into the economics of malaria falls into two categories: those studies that document the economic burden of the disease and those that examine the cost-effectiveness of interventions.

The Economic Costs of Malaria

The costs of malaria include the impact of the disease on the economy and economic development, on the local community, on the household, and on the individual. Precise estimates of the mortality and morbidity of malaria are often hard to come by; unsurprisingly, estimates of malaria's economic effect are correspondingly vague. The costs that malaria imposes are borne through increased mortality and through high morbidity rates. The impact of mortality varies with the age distribution of deaths, which in turn vary by ecological zones. In Africa and other regions where malaria is highly endemic and malaria deaths occur primarily among infants and young children, the effect of mortality is different, and will be perceived differently, than it is in areas of low to moderate endemicity where malaria deaths occur among the primary breadwinners or caretakers as well. Substantial secondary effects are attributable to adult deaths as surviving family members adjust to the loss of those with primary responsibility for the well-being of others. Increased infant mortality accompanies the loss of mothers; distress sales of assets to cover lost incomes of principal earners also increase. Arguably, the loss of an adult imposes greater emotional loss on survivors than the loss of infants, especially when infant mortality is generally high. (See Over and others 1992 for discussion of the consequences of adult deaths as a result of disease.)

Information on increases in morbidity is harder to obtain than data on mortality. Much of the research has concentrated on measuring the effects of bouts of illness in reducing productivity and, thus, output of workers. This research has been reviewed in Barlow and Grobar (1986). Research on the physical effects of the disease can be found in Conly (1975), Malik (1966), Russell and Menon (1942), and Van Dine (1916). Days of disability per case of malaria estimated in these studies range from five to twenty. Bhombore, Worth, and Nanjundiah (1952) estimate that families with malaria cleared only 40 percent as much land for crops as similar families without malaria. Conly (1975) traces a variety of adjustments in Paraguayan farm families afflicted with malaria, including increases in labor input by healthy family members per unit of output as well as reallocations of land and hired labor. The reallocations of land entailed substituting relatively low-value crops, whose crop season was not af-

ected by interruptions in cultivation due to malaria outbreaks, for higher-value crops that need more continuous cultivation. De Castro (1985) finds that such reallocations may also include an increase in the work load of healthy family members. This increase may be seen as an ameliorative factor in that it reduces the net effect of the disease, but it may also be seen as simply spreading the costs of the disease to others besides those who are ill.

The effect on reduced productivity is still a matter of controversy. Direct measures of physical ability have been made by Brohult and others (1981), who find no effect on productivity at all; however, a common convention in the literature is to assume that seven days of work are lost for each bout of malaria whenever this parameter is needed to assess a program but is not independently estimated (see studies by Niazi 1969, Quo 1959, San Pedro 1967, and Sinton 1935/36). When this parameter is independently estimated, it varies between five and fifteen days. A further issue, raised by Wernsdorfer and Wernsdorfer (1988), is the undermining of the effectiveness of investment in education. In areas where malaria is highly endemic, adults normally have acquired sufficient immunity to make the symptoms less severe, but schoolchildren are severely affected; repeated bouts of the disease can affect not only their attendance at school but also their ability to learn. Judging the degree of impairment caused by illness is difficult, and one can only speculate as to the cost.

Other studies emphasize direct financial benefits from activities made possible by eradication or control of malaria (see the survey of these by Wernsdorfer and Wernsdorfer 1988). For example, companies incur costs either when they bring workers who have no immunity to the disease into areas infested with malaria mosquitoes or when they forgo opportunities in the area to protect these workers from exposure. Griffith, Ramana, and Mashaal (1971) show the benefits, in the form of increased profits, that accrue from bringing miners who are not immune into areas where malaria has been eradicated. Forgone profits are the measure of the cost of the disease. Sinton (1935/36) documents many cases in India where the presence of malaria prevented an expansion into new territories, with substantial losses in forgone earnings. (These include as much as 60 percent of land in Bengal remaining idle and commercial ventures such as sugar estates in Assam being abandoned.) Demographic changes since then, however, have probably made it much harder to repeat such expansion in the subcontinent.

Valuing output from opening new lands leads to the broader question of how the *threat* of malaria affects peoples' behavior, a point stressed by Rosenfield, Golladay, and Davidson (1984). People have a range of options available to lessen the effect of illness or risk of infection, but these options have costs that are hard to assess. An example mentioned earlier is that farmers might plant relatively low-value crops—rootcrops, for instance—which are less sensitive to interruption of cultivation, if the possibility of illness makes interruption likely. The difference in the value of output between crops is rarely counted in these studies.

The tendency in cost estimation to confine attention to days lost from work or output forgone is oddly narrow. In welfare terms, the appropriate measure would be “willingness to pay” to avoid the disease altogether. This is sometimes referred to as the “equivalent variation,” or the amount that would need to be paid by a healthy person to feel as well off as when ill. An alternative measure could be the “willingness to accept,” or the “compensating variation,” which is the amount that needs to be paid to someone who is ill in order to return the afflicted person to the same level of well-being as he or she enjoyed before the onset of the disease. In contexts of price changes, these two measures should be quite close. In the context of measuring the burden of disease, the latter could be quite a bit larger than the former, since it does not depend on current ability to pay, which sets a limit on what could be paid (Hanemann 1991). In other words, the amount one would need to bribe someone to risk getting a potentially deadly disease may be much higher than the amount that person would be willing (or able) to pay to avoid that risk. Either of these measures would necessarily be larger than lost productivity alone, since they would include the subjective valuation of the discomfort and the fear of severe consequences—death—from the disease itself, as well as more easily measured losses.

The disadvantage of using a theoretically correct concept is that measurement requires a concerted research effort. A lower bound for how much people would be willing to pay can be inferred by calculating the total costs that people *do* pay to obtain treatment. The total costs borne by families and individuals include payment for treatment, time and transport costs in seeking treatment, time costs for family members who look after the patient, and the time and monetary costs of preventive action. The sum of these costs is only a lower bound because those who seek treatment reveal by their actions that they prefer to bear these costs rather than suffer the disease.

The true costs of the disease exceed the costs of seeking treatment for two reasons. First, there is pain and suffering before treatment is sought. Second, there are people who have decided that the costs of seeking treatment are too high relative to letting the disease run its course. For people in remote areas (who must pay very high transport costs to get treatment) or for those afflicted at peak agricultural seasons (when implicit wages are high, both for the person falling ill, or, in the case of children especially, for those needed to care for the person), these costs can be high. In addition, people who are uninformed about the potential benefits of treatment may suffer with the disease even when they would pay the costs of transport and treatment if they had better information.

In a careful study of Thailand, Kaewsonthi (1989) has attempted, among other things, to measure the costs borne by patients in seeking care. These costs amounted to \$20 per positive case, or nine times the average daily wage.² This estimate is for people coming to the malaria clinic and therefore does not include those who have handled the disease in other ways. The study includes costs entailed in seeking local treatment before travel to the clinic, which can be substantial. The degree of underestimation of the cost to sufferers is prob-

ably quite high. Time lost before and after seeking treatment can be considerable and varies with the quality (primarily speed) of service provided.

The situation is summed up by Andreano and Helminiak (1988, p. 35), who state that "despite the many studies and the excellent work by Barlow and Conly, which represent methodological advances in the study of tropical diseases, we remain woefully ignorant of the social and economic effect of malaria in those countries of the world where it is prevalent." They also emphasize that findings in many of these studies cannot be easily generalized from one area to another.

The Cost-Effectiveness of Interventions

Research has made some progress in estimating the burden of the disease, but estimates of the effect of policy instruments are less satisfactory. Because it is so difficult to conduct a complete cost-benefit analysis by the standards outlined earlier, cost-effectiveness ratios are frequently substituted. These are simply the ratio of the costs of an intervention divided by a given outcome, usually lives saved, cases prevented, or life years saved (sometimes corrected for quality or with discounting of future years). The idea is that these numbers can be compared and then choices made among alternative policies. But these ratios must be used with care and are sometimes misleading, as illustrated in the appendix to this article. Doubilet, Weinstein, and McNeil (1986) provide a number of grounds for caution, as does example 4 in the appendix. Nonetheless, cost-effectiveness ratios are the most widely used analytic technique and often the only game in town.

From the review paper by Barlow and Grobar (1986) mentioned earlier and the Nepal study by Mills (1987), the costs per year of lives saved and cost-benefit ratios can be calculated for malaria control efforts in several countries. These results are presented in tables 1 and 2. Included in table 1 are calculations of the cost per discounted quality-adjusted life years saved by the program. These calculations were made on the basis of the information, presented in the various studies, on costs per case averted or death prevented.

The most striking feature of these numbers is their variability. Indeed, the differences among the studies are so marked that it would be hard to make any generalizations about them at all. The costs per case prevented ranged from \$1.30 to \$260 (in 1987 dollars) and the benefit-cost ratios from 2.4 to 146; that is, the monetary benefits are between 2.4 and 146 times as high as the costs. The higher benefit-cost figures make malaria control seem of utmost importance. The lower figures bring it into competition with many other government programs or the costs of taxes to pay for them. Most of the explanation of the wide range of variation is not very illuminating. Differences in data quality, in assumptions used in the analysis (for instance, in ways mortality is estimated), in the definition of the relevant costs, in the length of time studied, in the discount rate applied, and in the coverage and purpose of the original intervention all account for much of this variation. As one example, in the

Table 1. Cost-Effectiveness of Malaria Control
(1987 U.S. dollars)

<i>Study</i>	<i>Country</i>	<i>Intervention</i>	<i>Cost per case prevented</i>	<i>Cost per death averted</i>	<i>Cost per discounted quality-adjusted life year saved</i>
Barlow (1968)	Sri Lanka	Insecticide	—	78	3
Cohn (1973)	India	Insecticide	2	—	7
Gandahasada and others (1984)	Indonesia	Insecticide	83–102	—	275–6,180
Hedman and others (1979)	Liberia	Vector control; drug therapy	14	—	143
Kaewsonthi (1989); Kaewsonthi and Harding (1984)	Thailand	Vector control; drug therapy	27–74	—	90–760
Mills (1987)	Nepal	Vector control; drug therapy	1–172	3–255	—
Molineaux and Gramiccia (1980)	Nigeria	Vector control; drug therapy	259	—	1,500–2,650
Ortiz (1968)	Paraguay	Insecticides	60	—	71
Walsh and Warren (1979)	Developing countries	Vector control	—	990	34

—Not available.

Note: Figures are rounded to the nearest dollar.

Sources: Barlow and Grobar (1986); Mills (1987); authors' calculations.

Table 2. Benefit-Cost Ratios in Malaria Control

<i>Study</i>	<i>Country</i>	<i>Intervention</i>	<i>Benefit-cost ratio</i>
Barlow (1968)	Sri Lanka	Insecticide	146.0
Griffith, Ramana, and Mashaal (1971)	Thailand	Chemoprophylaxis	6.5
Khan (1966)	Pakistan	Eradication program	4.9
Livandas and Athanassatos (1963)	Greece	Eradication program	17.3
Niazi (1969)	Iraq	Eradication program	6.0
Ortiz (1968)	Paraguay	Insecticide	3.6
San Pedro (1967)	Philippines	Eradication program	2.4
Democratic Republic of Sudan (1975)	Sudan	Control program	4.6

Source: Barlow and Grobar (1986).

Garki Project study (Molineaux and Gramiccia 1980), which generated the figure of \$260 per case averted per year, the costs of the extensive research and monitoring exercise that accompanied the intervention are included in the program costs.

Similarly, some of the studies included administrative costs, while others used only the cost of materials. Some costs were calculated on the basis of small pilot projects (Gandahasada and others 1984 in Indonesia) and others on the basis of national efforts (Barlow 1968 for Sri Lanka). The costs per quality-adjusted life years are sensitive to assumptions concerning case fatality rates for those countries with data only on cases averted per year.³ Differences in research methods of these sorts would make it difficult to find a reliable cost figure even if it were unambiguously defined and common to all of the studies.

That the return to investments differs in different locations and circumstances should not be surprising. There are at least four systematic reasons for the wide variations in the cost-effectiveness numbers presented in the tables. Each points to an area of ignorance that limits the relevance of the calculations to policy. These are: (a) differences among areas in their ecological, epidemiological, and social characteristics; (b) wide variations over time of the incidence and severity of malaria within a particular area; (c) variations in the organizational structures of control programs; and (d) differences in the intensity with which the interventions are applied.

STRATIFICATION. The variability in the epidemiology among regions determines much of the effectiveness of control programs, with the degree of endemicity being the most important variable. Also of importance are characteristics specific to a region, such as the traits and habits of the mosquito population, the openness of the area to migration of vulnerable populations, and the degree of parasite resistance to chloroquine. For any particular policy analysis, the local conditions must be assessed. Little information is widely generalizable.

TEMPORAL VARIABILITY. Depending on the degree of endemicity, the prevalence of malaria can vary substantially within the same region over time. Calculations of the cost-effectiveness of control efforts will similarly vary (inversely with the prevalence rate); the usefulness of cost calculations that use a single base year as a comparison for a program are therefore limited. Policy options must be evaluated on the basis of their expected value averaged over the distribution of prevalence occurring at different times for the area. This is particularly important if costs include a fixed component—for example, the administrative costs for control organizations—that must stay in place regardless of the prevalence in any one year.

ORGANIZATIONAL STRUCTURE. Control programs vary from highly structured, single-purpose, vertical programs to “integrated” health services where all disease conditions are the responsibility of the local health authority. As a matter

for policy design, joint costs between the provision of health care generally and malaria control programs in the integrated schemes must be assessed. This assessment can help in deciding to what extent malaria control operations should be operated independent of the local health center. Mills (1987) finds that the higher the volume of cases, the more similar the costs of integrated and free-standing programs are likely to be. In areas in which case load is low, integrated programs can have substantial cost savings as personnel shift their attentions to other health care needs.

RETURNS TO SCALE. As discussed in the description of the ideal world, costs and effectiveness vary substantially with the level of activity of the intervention. Certain costs of intervention programs, such as facilities and staff salaries, are relatively fixed. Others, such as costs of materials (drugs), are variable and proportional to outputs. And still others, such as costs of spraying when more dispersed populations are covered, rise more than proportionately with output. Because none of the studies cited gives more than an estimate of costs at a given point, these estimates are difficult to incorporate into a thorough analysis.

Because there are good reasons to expect diminishing returns to most single activities for controlling malaria, effective policies are likely to entail a package of instruments. Costs for mosquito control activities rise as densities of mosquitoes and of people decrease. Costs for case management operations rise as it becomes necessary to move from passive case detection methods to more costly public awareness campaigns, such as information, education, and communication (IEC) campaigns, or even to active case detection. Barlow and Grobar (1986) suggest that the great uncertainty surrounding cost estimates argues that a combination of policies should be used to control parasitic diseases—in the same way that financial managers use a portfolio of investment instruments rather than investing everything in a single instrument that could fail. The argument could be made for malaria, at least, that a combination of policies would be desirable, even with accurate information, because of the diminishing returns to any one instrument.

Specific Interventions: What Do We Need to Know?

One inference that can be drawn from the preceding argument is that the effects of particular interventions need to be assessed in specific contexts and are not likely to generalize much from one context to another. Further, when considering the use of *public* funds to control the disease, the appropriate measure for effectiveness of a policy must be the increase of the use of a control instrument and the lives saved by it over and above what a private market would provide without government help. For some antimalarial operations, such as mosquito control, the service provided is a pure public good—if the public did not provide it, it would not get done at all. For other activities, such

as drug therapy for people who show up at clinics, public provision may only substitute for private. If private provision is inadequate—due, perhaps, to imperfect information for consumers of the value of treatment—public intervention may be called for. Whether the intervention should be treatment or a public information campaign needs to be assessed. The functioning and performance of private markets should be examined when public interventions are proposed.

In vector control operations, spraying inside homes, or residual spraying, will continue to be the principal tool in most areas. Theoretical justification for this comes from the effects of the various techniques on the variables determining vectorial capacity. Residual spraying has a strong immediate effect on vectorial capacity and hence works directly on the mortality rate, whereas the other techniques—land management, larvacides, or drainage—work primarily through decreasing vector density over time (Rishikesh, Dubitiskij, and Moreau 1988; Molineaux 1988). This immediate advantage is not sufficient to infer the superiority of residual spraying, but costs do not differ so much as to overturn that conclusion. The degree to which spraying can be effectively used, however, varies substantially with the endemicity of the disease, and the costs can differ substantially at different levels of use. To what extent spraying is effective needs to be decided locally. Other techniques of vector control, such as outdoor spraying of specific mosquito breeding grounds or drainage of swamps, can be effective in very specific settings but are subject to distinct limits on the extent of their use.

For case management, drug therapy will continue to be the principal antimalaria tool. The material cost of drugs is easy to assess. The full costs of drug therapy as a public policy, however, depend on the efforts (either by the individual or the health care system) to get the patient to seek treatment. These will vary from place to place, as will the rate at which costs of active case detection or public awareness campaigns rise with greater coverage of the population. Public information campaigns could also improve the way people use the drugs—the mosquitoes' resistance to chloroquine, for instance, has been exacerbated because many people stop taking the drug before the full cycle has been completed. But there is little information available on how much such a campaign would cost or how effective it might be.

Personal protection methods, such as using bed nets or curtailing evening activities, could be influenced by informing the public—but again, there is little information on how effective this educational effort would be. The same might be said of subsidies on the sale of bed nets. An assessment of the costs and the benefits would require guessing how responsive to price the demand for bed nets might be.

Surveillance can reduce costs and improve the functioning of control operations. For example, in areas where malaria is a recurrent but not perfectly predictable problem, the value of vector control varies substantially. Surveillance activities have some fixed costs that are independent of the prevalence rate—the cost of a parasitology laboratory or of the entomological service—but can save

the cost of spraying when the prevalence rate does not justify the operation. The value of surveillance for this purpose can be described theoretically (see Kaewsonthi 1989; Harding 1984; Hammer 1992), but it has not been quantified.

The challenge of drug resistance points to another gap to be bridged by cooperation between economics and epidemiology. Little has been done in the way of combining analyses of the dynamics of the disease and the value of interventions. Drugs can induce resistance as well as cure the disease. If the relationship between current drug use and the development of resistance in the parasite were known, such future effects might be taken into account in designing policies concerning pricing, regulation, and information campaigns. Vector resistance to insecticides tells the same story. Once again, however, merely tracking the pattern of resistance development is not sufficient for policy analysis: the rate of the spread of the resistant strain must be tied to variables that are under the policymaker's control.

Integrating knowledge of the dynamic properties of the disease with economic analysis could be beneficial in more general ways. Depending on the degree of endemicity, policies can have effects over varying periods of time. The most dramatic effects may be expected in areas of low endemicity where eradication is a possibility. However, even in areas of high infestation, real, although more limited or temporary, gains may be possible. Short-run benefits that are eroded over time may still be worthwhile. The dependence on policy variables of the interrelated time-paths of vector density, immunity development, resistance development, and human disease has yet to be determined. Wiemer (1987) provides an application of optimal control techniques to a dynamic model for schistosomiasis in China, but this has not been replicated for other diseases.

Research

Much of the best recent work in the economics of malaria control has been operationally oriented, designed to answer specific questions concerning service delivery. When specific activities are proposed for a specific area, costs can be gauged relatively easily, because changes in scale are not at issue. Marginal benefits can also be appraised in terms of the local epidemiology and institutional and administrative conditions. Costing exercises in these cases can greatly improve allocation decisions by managers; the work done by Kaewsonthi (1989) in Thailand and by Mills (1987) in Nepal are examples of how useful such studies can be. These studies used careful costing procedures at local levels to clarify comparisons between techniques of vector control and between vector control and therapy, and to make practical recommendations for improvements. Mills, for example, was able to suggest that active case detection methods be reduced and the number of malaria clinics (or other treatment-based facilities) be increased—and that either of these activities looked better than spraying.

One of the few studies that has been sensitive to the issue of decreasing effectiveness was done by Ettlting and others (1990). In this study, the increasing costs

of expanding clinic coverage in a district in Thailand are documented and presented in a form that makes clear the tradeoff between numbers of cases treated and the cost per case.

Recent work at the U.S. Centers for Disease Control (Sudre and others 1990) has focused on the choice of drug therapy in areas of chloroquine resistance and identifies the variables salient in this decision. Interestingly, the study finds one of the most important factors relevant to the choice of drugs to be the relative compliance with drug regimens—an indication that information and other measures to improve compliance should be explored.

Work in progress at the Centers for Disease Control has highlighted the problems of infant and child mortality in malaria-prone regions of Africa. One conclusion emerging from that work is that prenatal prophylaxis, early in pregnancy and especially for first pregnancies, can be effective in averting low birth weight and related infant mortality. From a policy perspective, this raises the issue of how to get women who have not felt sick from malaria for years, and who do not seek prenatal care in any case, to take preventive measures. Once again, questions about the cost-effectiveness of information campaigns loom large.

Many of the questions that need to be tackled in policy analysis for malaria have been addressed in other areas. On the regulation and control of drugs, a review by Foster (1990) shows the scope of cost savings and improved health outcomes that can come from more effective use of drugs in Sub-Saharan Africa. Misdiagnosis, errors in prescription, and failures in compliance appear as important issues, raising the problems of providing information to a decentralized and largely private market. A more theoretical approach is taken by Hammer (1992), who examines the relative merits of selling drugs over the counter rather than by prescription, balancing access and affordability with accuracy in drug use.

Policies to control malaria will have to include many activities that involve improving public awareness and modifying personal behavior. The costs and effectiveness of public information campaigns have been studied in a number of contexts not specifically related to malaria control. Existing studies on family planning and, in industrial countries, on behavioral changes in diet and lifestyles may be of use, but, given the very different contexts and issues, these may serve only as examples of what might be done.

Finally, dynamic models of epidemiology have been integrated with economic policy models for other parasitic diseases such as schistosomiasis (Wiemer 1987). The potential value of similar work on malaria is great.

Agenda for Research and Operations

The main thrust of my arguments has been that appropriate policies will often entail a mix of interventions, that this mix will vary from one quite small

region to another, that circumstances change (especially in regard to drug resistance), and that the information needed to assess the effectiveness of each intervention often does not exist. These considerations underline the need to develop local institutional capacity for generating policies suited to local needs. No single set of policies will be applicable globally, except for a general policy of strengthening institutions charged with the health of the public and encouraging the collection of more data. Policies can only be more precisely specified in the field.

Making intelligent choices among different strategies, learning from experience, and being able to change these strategies to suit the circumstances all require considerable expertise in epidemiology and in operationally oriented research, in economics among other disciplines. This expertise is needed to varying degrees at the local and national levels. Maintaining well-organized programs (whether specialized in malaria or not) with well-trained people is an important task, but by no means an easy one.

In Africa and other areas where malaria is highly endemic, the range of policy options specific to malaria is somewhat more limited than in areas where endemicity is lower. In these circumstances, the emphasis should be on improving health care delivery overall. The policies in question relate to the financing of health care, public investments, location of facilities, and campaigns aimed to inform the public and the providers about drugs, therapy options, and protective behavior.

It is safe to say that one general need is to improve routine collection of information. This, of course, will be of value beyond the application to malaria alone. The information needed is largely epidemiological, narrowly defined, but with an emphasis on those variables that policy can manipulate. The functional dependence of these risk factors on the policy options must be explored to be useful.

All the steps in the decision process outlined in our "ideal world" are surrounded by uncertainty. In each context, the information to be collected and the appropriate set of policies will be different. Research on one class of policy options may be applicable in a range of situations: information, education, and communication programs, or health education generally may have substantial value in improving drug compliance, in seeking prenatal care, in recognizing symptoms in cooperation with vector control operations, and in adopting personal protection measures. The costs and effectiveness of providing this information are not well known, however; neither are the effect of this information on behavior or the effect of behavior on incidence. Given the potential benefits, applied research in this particular area may yield substantial returns.

Appendix: Some Economic Concepts Relevant to Malaria Control

This appendix uses five examples to illustrate some fundamental economic concepts relevant to the points made about disease control in this article. The

first point is that the absolute magnitude of the burden of a disease is *not* a proper criterion for setting priorities in health. The second is that changes in costs that might be expected to occur at different levels of intensity of activity affect the optimal allocations of resources. The third is that this pattern of costs can imply that a mix of techniques may be appropriate in malaria control; the fourth, that average cost-effectiveness is also not a proper criterion for priority setting; and the fifth, that cost effectiveness ratios cannot be used to compare activities that are mutually exclusive, such as curative care options for a given disease.

Example 1: Disease burden and priority setting. Consider the following simple example. There are two diseases. Disease A kills 1,000 people a year and disease B kills 30 people a year. It so happens that it costs \$100 to save one person from disease A and \$50 to save that person from disease B. The ministry of health has \$10,000 for disease control. How should it be spent?

If priorities were set by ranking diseases by “importance,” that is, by mortality rates, disease A would win hands down because it kills more than 30 times as many people as disease B. If all resources were devoted to disease A, the ministry could save 100 lives ($\$10,000 \div 100$). If resources were devoted to each of the diseases in proportion to their mortality rates, disease A would receive \$9,700, B would get the rest, and 103 lives would be saved—6 from disease B using the \$300, and 97 from A. The ministry could have done even better, though, had it used the entire \$1,500 needed to eradicate the less “important” disease B and used the remaining \$8,500 on the more “important” disease. With that strategy, 115 lives would be saved—30 from B and 85 from A.

In this example, priorities set by considering the burden of the disease are exactly backwards. The disease with the lower total burden, not the more prevalent one, is the first priority. The point is that priorities depend on what can be done about a problem, not how big the problem is. Interventions should be ranked in order of the marginal effect, that is, the effect of one more unit of input—dollars, or hours, or patients seen. The interventions should be conducted in that order until the budget is exhausted (as in this case) or until the marginal effect of the first intervention is no longer greater than the (again) marginal cost of other uses of these funds. For example, if it were decided to spend no more than \$60 per life saved (either because that is how much saving lives from all other causes would cost or, more contentiously, because someone decided that was what lives are worth), then only disease B would be attacked because only B meets this criterion. Disease A would be ignored.

Example 2: Decreasing returns. In this case, costs of controlling disease B remain \$50 per life saved, but those of disease A vary in the following way. One hundred people can be saved at a cost of \$25 apiece, but the remaining 900 would cost \$100 apiece, as in the first example. This differential could occur because there are different techniques for dealing with the disease and the

cheaper technique is subject to some capacity limits. Alternatively, there could be only one technique that becomes less effective as use increases because it faces more difficult environments. For example, drug therapy may be cheap for those who present with symptoms but may be very expensive if active case detection is necessary to expand coverage to those who do not seek treatment.

With this cost structure and the same \$10,000 budget, what is the best thing to do? If disease A is a priority because of the burden-of-disease argument, 175 lives can be saved—100 at a cost of \$2,500 and 75 at a cost of \$7,500. But again, more lives could be saved if the criterion of what can be done, rather than which is the biggest problem, is used. On that criterion, the \$25 technique for disease A would be used, saving 100 lives for \$2,500. Next, attention would turn to disease B where 30 lives could be saved for \$1,500, and the remaining \$6,000 could be used for the more expensive technique for controlling A, thus saving 60 lives, for a total of 190 saved altogether. These 15 extra people are the same as those saved in the first example. If, instead of thinking in terms of a budget constraint, we were comparing marginal benefits with the marginal cost figure of \$60 as above, the first 100 people from A and the 30 people from B would be saved, leaving the remainder of the money to be used elsewhere in the health sector (or in the rest of the economy).

Figure 1. *Decreasing Returns: Lives Saved in Relation to Money Spent*

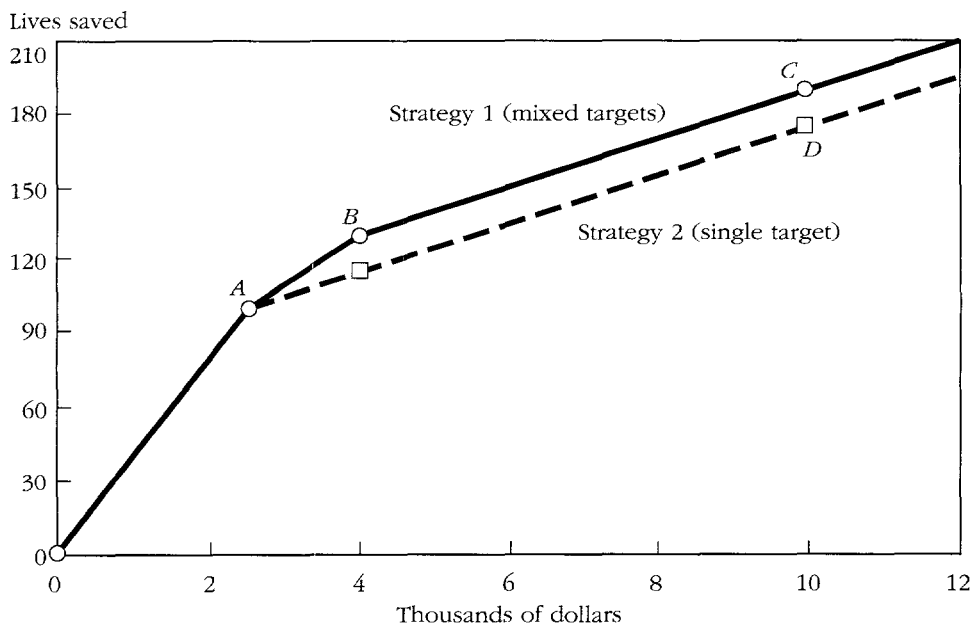


Figure 1 illustrates these points. The diagram shows the relation between money spent and lives saved following the different strategies. The path *OABC* (strategy 1) represents the strategy of using the \$25 technique (from *O* to *A*) for disease *A*, followed by attention to disease *B* (*A* to *B*), and finishing with a return to the less effective technique for *A* (*B* to *C*). Had all resources gone to disease *A*, following the path *OAD* (strategy 2), the opportunity to reduce mortality caused by disease *B* would have been missed.

Example 3: More decreasing returns. In this example there is only one disease but two types of intervention. Let the cost structure for *A* in the second example refer to vector control (that is, the first 100 lives cost \$25 apiece and the additional lives cost \$100 apiece). This difference could be attributable to high returns to focal spraying, which is of limited applicability, and low returns to more widespread control operations. With passive case detection techniques, 200 people could be treated at a cost of \$10 apiece. If active detection services are required, the cost rises to \$33.33. With the same budget constraint of \$10,000, the optimal policy intervention is to treat the 200 people who come to the clinic (at a cost of \$2,000), do focal spraying, saving 100 lives (at a cost of \$2,500), and use active detection methods until the remaining budget of \$5,500 is exhausted, saving 165 more lives. Note that this strategy involves using a mixture of techniques because of the increasing costs (or, equivalently, decreasing returns) to the use of each type of intervention alone.

Example 4: Average versus marginal costs and benefits. This example illustrates the importance of obtaining the relevant information about the true effect of interventions “on the margin,” rather than on average. The example involves two techniques—vector control and drug therapy. Focal spraying is very effective—it costs \$10 a life and can save 200 lives. After that, the cost of spraying jumps to \$100 a life. Drug therapy costs \$40 a person. The country’s current program simply splits the budget in half, giving \$5,000 to vector control and the same to malaria clinics. It is saving 355 lives (200 from focal spraying costing \$2,000; 30 from the remaining \$3,000 from vector control); and 125 ($\$5,000 \div 40$) from therapy. An accountant comes along to appraise the program and discovers that the average cost of a life saved by vector control is only \$21.74 ($\$5,000 \div 230$) while drugs cost \$40 a life; the accountant therefore recommends expanding vector control operations at the expense of the clinics. This is exactly wrong. While the *average cost* of vector control operations is \$22, the *marginal cost* is \$100 because the country has already exhausted the limits of focal spraying (which substantially increased the calculation of average effectiveness) and is relying on the less effective techniques. The correct advice to give is to cut back vector control funds to \$2,000, which covers focal spraying, and use the remaining money for drugs. This strategy increases the number of lives saved to 400. The accountant’s advice would have reduced the number saved.

Example 5: Mutually exclusive options. One last example illustrates a general problem with applying cost-effectiveness analysis to choices between competing, mutually exclusive options.

Consider a situation in which two drugs are available to treat a particular disease. Drug 1 changes the probability of avoiding death from 0.2 to 0.3 and costs \$5 per treatment. Drug 2 changes the probability from 0.2 to 0.25 and costs \$2 per treatment. The cost per life saved by drug 1 is \$50 ($\$5 \div [0.3 - 0.2]$), while lives saved by drug 2 cost \$40 ($\$2 \div [0.25 - 0.2]$), making drug 2 more cost-effective.

Most people probably would opt for drug 1, though, provided they are willing to pay more than \$60 to save their life. For any imputed value of life greater than \$60, the value of the increased probability of recovery outweighs the extra cost of the drug. That is, at \$60, the net return to drug 1, $\$60 \times (0.3 - 0.2) - 5 = \1 , is equal to that of drug 2, $\$60 \times (0.25 - 0.2) - 2$, and is higher for any value greater than \$60. Cost-effectiveness ratios, while seeming to avoid the contentious issue of deciding on a monetary value of life, merely disguise an implicit valuation that may not reflect people's preferences. Mutual exclusivity characterizes all comparisons of alternative treatment options for a given disease, and this rules out cost effectiveness ratios in the analysis of curative care.

Notes

The author is on the staff of the Population and Human Resources Department of the World Bank. The article draws on work done for the Institute of Medicine study of malaria (Oaks and others 1991) and on Nájera, Liese, and Hammer (1992).

1. The number of years saved—in the case of mortality—by health intervention, weighted by a term capturing the degree of unpleasantness caused by the morbidity of a disease, and discounted to conditions in the future.

2.. All dollar amounts are U.S. dollars, unless otherwise noted.

3. Following Lancaster (1990), a case fatality rate of 1 percent was assumed for India, 0.25 percent for Liberia and Nigeria, 3 percent for Paraguay, and from 0.2 percent to 1 percent for the rest of Asia, on the basis of the India figure and data from Malaysia.

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