The Economic Benefits of Malaria Prevention: A Contingent Valuation Study in Marracuene, Mozambique

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Abstract

A contingent valuation (CV) survey was conducted in Marracuene, Mozambique, a very low-income, malaria-endemic community about 50 kilometers north of Maputo, to estimate adults' perceived economic benefits of avoiding malaria. Interviews were conducted with 282 individuals in which respondents were asked whether they would purchase a hypothetical malaria vaccine that would prevent malaria for one year if it cost them a specified price. The average respondent's willingness to pay to avoid the (high) risk of contracting malaria for one year was approximately US$14, equivalent to about seven chickens in the local economy. Their responses to these CV questions suggest that the economic benefits to even very poor individuals are larger than many observers have assumed, and that the potential revenues available from low-income rural communities may be substantial. The estimates of the average adult's willingness to pay for the malaria vaccine are the three to four times higher than estimates based on a simple cost-of-illness approach.

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The ***Journal of Health and Population in Developing Countries (ISSN 1095-8940)***
is a publication of the Department of Health Policy and Administration, School of Public Health
University of North Carolina at Chapel Hill.

1. Introduction

It is widely recognized that malaria is one of the most serious infectious diseases in the world, and that it causes immense human suffering and economic losses. The international community has been working on malaria control, prevention and treatment efforts for decades, with much of the focus on the development of a malaria vaccine. The effort to develop a vaccine has been largely "supply-driven," in the sense that most of the major resource allocation decisions have been made by international organizations, national governments, and health professionals without the active participation of the potential beneficiaries of malaria prevention, treatment, and control. Economic criteria have rarely been used to justify budget allocations or expenditures. One result of this supply-driven approach has been that the funds devoted to malaria control and prevention efforts by international organizations and national governments have been largely determined by centralized budgetary decisions in which potential beneficiaries have little ability to either influence decisions or contribute financial resources. The options available to people themselves are largely limited to paying for treatment when infection occurs and efforts by individuals to avoid infection (e.g. the use of bednets, placing screens on windows, and eliminating local sources for mosquito breeding).

Little attention has been paid to how people at risk of malaria in developing countries perceive the magnitude of the economic benefits of malaria prevention. Even the few efforts to estimate the economic benefits of malaria control have used methodologies that utilize little primary information on people's actual preferences. Typically, the economic losses associated with malaria morbidity are based on direct medical and other expenses incurred and productivity loss calculations (e.g., perhaps multiplying an estimate of the average number of days of work lost by patients and caregivers by the average wage).

In this paper we take a different approach to estimating the economic benefits of malaria prevention. We ask individuals themselves how much they would pay to avoid the risk of being infected. A contingent valuation (CV) survey was conducted in Marracuene, Mozambique, a very low-income, malaria-endemic community about 50 kilometers north of Maputo in the coastal region of Mozambique. Interviews were conducted with 282 households in which respondents were asked whether they would purchase a hypothetical malaria vaccine that would prevent malaria for one year if it cost them a specified price. Their responses to these CV questions suggest that the economic benefits to even very poor individuals are larger than many observers have assumed, and that the potential revenues available from low-income rural communities may be substantial.

In the second section of this paper, we describe the study area. The third section summarizes the malaria situation in Marracuene.[1] The fourth section presents the study and questionnaire design and describes the survey implementation. In the fifth section, we present the survey results, including multivariate analyses of the determinants of respondents' demand for the hypothetical malaria vaccine. In the sixth section, we compare the estimates of the economic benefits of malaria control obtained from contingent valuation results with some simple estimates of household productivity losses. In the seventh and final section, we summarize our findings and suggest areas for future research.

2. Description of the Study Area

The community of Marracuene is in the District of Marracuene, located on the Indian Ocean north of Maputo, the capital and largest city of Mozambique.[2] The Inkomati River crosses the District of Marracuene; the center of the town of Marracuene is on a high bluff overlooking the river, only 10 kilometers from the sea. In 1994 Marracuene had a population of about 28,000 people, although this is only an estimate since many people fled during the Mozambique civil war, and are gradually returning.

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[1] In the Appendix we present a brief overview of the malaria situation in Mozambique generally.
[2] In this paper we refer to the community as "Marracuene;" when we refer to the district of Marracuene, we will indicate this.

On the other hand, refugees from other locations have migrated to town and built semi-permanent housing. Considerable fighting occurred in the center of town during the civil war, and many of the buildings and shops were destroyed or abandoned.

It is about a 45-minute drive from Marracuene to Maputo. Many people in Maputo cultivate small plots (*machambas*) in the District of Marracuene, and many people in Marracuene work in Maputo during the week and return home on weekends. At the time of the fieldwork in 1994 market institutions were not yet flourishing in Marracuene. There was no land or real estate market; land was distributed by the city's executive council through administrative procedures. Nor were there active labor or credit markets. Nonetheless, Marracuene's economy was in transition, and prices for many commodities were approaching international levels (see Table 1). The income distribution was quite skewed. On the one extreme were households with a member employed in Maputo that could participate in the emerging market economy. On the other were households largely engaged in subsistence agriculture with little access to markets.[3] Neither group, however, had much income by international standards.[4]

By Mozambique standards, Marracuene is a relatively well-off town. Marracuene is served by a national highway and a railway, both linking the town to Maputo. The center of town is a well-laid out, planned area of a few square blocks with some paved streets. There is a petrol station, two markets, and an important textile factory. The national electricity and telephone companies also serve the town. A piped water distribution system, although unreliable, provides free water through three functioning public taps. Less than 100 households, largely in the town center, have a private connection to the water distribution system.

Table 1: Prices of Goods and Services in Marracuene (November 1994)

Item	Price (meticais)[5]	Price (U.S. $)
1. Rice (1 kilogram)	2,500	$0.38
2. Cooking oil (1 liter)	10,000	$1.54
3. Chicken	13,000	$2.00
4. Goat	160,000	$25.00
5. Pig	400,000	$62.00
6. Meat: beef (1 kilo)	20,000	$3.00
7. Loaf of Bread	2,000	$0.31
8. Beer (bottle)	5,000	$0.77
9. Cola or other soft drink		
Domestic:	2,000	$0.31
Foreign:	4,000	$0.62
10. Charcoal (bag)	10,000	$1.54
11. Round-trip bus ticket to Maputo	2,000	$0.31

[3] Three fourths of Mozambique's population lives in rural areas.

[4] According to the World Bank (1995), Mozambique has the lowest GNP per capita (US$ 90, in 1993) of any country in the world. According to an index of human development constructed by the UNDP, which takes into account life expectancy, education and income, the three with equal weights, Mozambique ranked 157th among the 173 countries for which estimates are available [Mozambique (1994)].

[5] In November 1994, U.S. $1 = 6500 meticais; the exchange rate on the black market fluctuated somewhat during the month.

3. Malaria Situation in Marracuene

Malaria is endemic in Mozambique in general and in Marracuene in particular. Infection is common throughout the year, but is highest in the hot season from October to April. In our 1994 household survey, respondents were asked whether they had ever had malaria; over two thirds said they had (Table 2). Fifty percent of the respondents reported that they had had malaria over the past two years; 10 percent said they had had malaria four or more times over the past two years. Seventeen percent reported that they knew someone who had died of malaria during the past year.

Most people said their malaria symptoms lasted a week or less. Almost everyone that had had malaria said that they took medicine to treat it (96 percent). Many people visited traditional healers before seeking modern medical treatment from health clinics or the hospital.[6] Although resistance to most drug treatments is high in Mozambique (see Appendix), the most common modern medicine used was still chloroquine, which sold at the hospital for 100 meticais (US$0.02) for a package of ten tablets. The market price of a packet of ten chloroquine tablets (sufficient for a normal treatment regime) was 5000 meticais. The market price for a packet of three tablets of Fansidar, one treatment option for more difficult, chloroquine-resistant malaria cases, was 15,000 meticais.

Habitats for mosquito breeding are found throughout the community. For example, because some people dig small channels from the river to irrigate their crops, there is standing water in many places in the fields. Around the majority of houses, there are also breeding sites for mosquitoes such as rainwater in broken coconut shells. Although people in Marracuene have a good understanding of how they become infected with malaria, little effective prevention is accomplished. Mosquito nets are perceived to be too expensive and a bother to use.[7] Many families burn green wood and leaves inside their homes to keep mosquitoes away.

Marracuene is one of the few communities in Mozambique, outside of Maputo, with a physician, who works in a twenty-five-bed hospital near the center of town. Malaria is the most common reason people come to the hospital for consultation. The hospital is equipped with a laboratory staffed by a trained technician who conducts blood tests to confirm malaria infections. Thus, data on malaria cases are available in Marracuene that exist in only a few other communities in Mozambique. In 1993, 10,205 people were treated for malaria at the Marracuene hospital (Table 3). Approximately one third of these were confirmed by laboratory test. Thirty-seven percent of those treated were children.

The vast majority of infected individuals who come to the hospital are treated as out patients. There were only 120 inpatients with malaria in 1993; the majority of these were children (72 percent). The average stay of in-patients with malaria was five days for children and eight days for adults.[8] Most in-patients recover from malaria. Of the 86 children admitted to the hospital with malaria in 1993, 22 percent died (although not necessarily from malaria). There were no deaths of adults attributed to malaria, in part because the most severe cases are transferred to Maputo for more intensive treatment.

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6 Traditional remedies include the use of leaves and roots of the *cacana* plant.

7 A normal-size (unimpregnated) mosquito net in Maputo cost approximately 150,000 meticais (US$23) in November 1994.

8 Many patients admitted for malaria suffer from more than one disease, so the average length of stay cannot be attributed solely to the malaria infection.

Table 2: Malaria Situation in Marracuene (1994)

Malaria Questions	Possible Answers	Frequency	Percent
Have you ever had malaria?	Don't Know	13	4.6
	No	75	26.6
	Yes	194	68.8
How many times have you had malaria over the past two years?	Number of times:		
	0	140	49.5
	1	53	18.8
	2	40	14.2
	3	20	7.1
	4	17	6.0
	> 5	12	4.3
How long did the malaria last?	Days		
	1	5	2.9
	2	21	12.1
	3	21	12.1
	4	10	5.8
	5	8	4.6
	6	2	1.2
	7	45	26.0
	10	3	1.7
	14	28	16.2
	≥ 15	30	17.4
	N = 173 Mean = 10.7 Std. Dev. = 11.4		
Did you take any medicines?	No	7	4.2
	Yes	161	95.8
How much did the last malaria medicine you purchased cost?	N = 133 Mean = 4,536 meticais Std. Dev. = 13,496		
How many people do you know who have died of malaria during the past year?	No answer	57	20.2
	0	186	66.0
	1	15	5.3
	2	6	2.1
	3	9	3.2
	≥ 5	9	3.3

Table 3: Number of Malaria Cases in the Marracuene Hospital -- 1993

	Children	Adults	Total
Confirmed by Laboratory Test	1,673	1,484	3,157
Not Confirmed but Treated with Chloroquine	2,098	4,950	7,048
Total	3,771	6,434	10,205

Source: Data obtained directly at the Hospital in Marracuene.

4. Research Approach

The contingent valuation survey was conducted in Marracuene over a four-week period in November 1994.[9] Two weeks were spent developing and pretesting the questionnaire, and training a team of 10 enumerators. Seven focus groups were held in several different community settings (e.g. a local restaurant, market, and informal gatherings of people in neighborhoods) during the development of the questionnaire. In total, 282 household heads or their spouses were interviewed. Because a sampling frame was not available, it was not possible to follow a rigorous random sampling protocol. Enumerators were dropped at many different locations throughout all neighborhoods (*bairros*) in the community, and instructed to walk in a specified direction and interview every fourth household. Many of the interviews were conducted in the early morning, evenings, and on weekends in order to increase the enumerators' chances of finding the main wage earners at home.

The majority of people in Marracuene speak *Ronga*, a local dialect. Portuguese is taught in schools and is spoken by many people in Marracuene. *Ronga* is rarely written, but to ensure that enumerators asked the questions in the survey instrument in exactly the same way, we prepared both Portuguese and *Ronga* versions of the questionnaire. Enumerators asked respondents in which language they preferred to be interviewed; 53 percent of respondents chose to conduct the interview in Portuguese, 47 percent in *Ronga*. Very few individuals who were approached by enumerators refused to be interviewed.

The survey instrument included: (1) a contingent valuation section designed to estimate the respondent's willingness to pay for a malaria vaccine, (2) a series of questions about the respondent's experience with malaria, (3) questions about the respondent's and household's demographic and socioeconomic characteristics, and (4) some additional questions about the respondent's attitudes and priorities. In the contingent valuation section, the respondent was presented with the following choice:

> Suppose there was a shot (injection) that you could get that would prevent you from getting malaria for one year. Suppose that this injection cost [15,000 / 50,000 / 100,000 / 200,000] meticais. Would you choose to pay for this injection for yourself or not?

Enumerators recorded one of three possible answers: "yes", "no", or "don't know / not sure." Each respondent was asked only one of the four indicated prices. These four prices were chosen based on pretest results to span a wide range of population acceptance rates (i.e., in order to estimate how the price charged affected the percentage of the population that would purchase the vaccine). The price a specific respondent received was randomly assigned and outside of the control of the enumerator. Seventy-three respondents received a price of 15,000 meticais; 73 also received a price of 50,000 meticais; 71 received 100,000 meticais; and 66 received 200,000 meticais.

9 For additional information on the administration of the contingent valuation survey, see Pinheiro and Whittington, 1995.

5. Results of the Analysis

Table 4 presents the percent of respondents in each split-sample (i.e., at each price) that indicated they would purchase the malaria vaccine injection. As shown, respondents' answers were clearly influenced by the price of the vaccine that they were given. Seventy-five percent agreed to purchase the vaccine if the price was 15,000 meticais; 55 percent if the price was 50,000 meticais; 27 percent if the price was 100,000 meticais; and 19 percent if the price was 200,000 meticais. Eleven percent of the respondents gave "don't know" answers. In subsequent analyses, we have treated "don't know" answers as "no's." This is the conservative assumption in terms of lowering willingness to pay, and the enumerators felt it was likely the correct characterization of most of these respondents' preferences.

Table 4: Willingness to Pay for Malaria Prevention

Price Given to Respondent (meticais)	Respondent's Answer: Yes (%)	No (%)	Don't Know / Not Sure (%)	No Answer (%)
15,000	75.3	16.4	5.5	2.7
50,000	54.8	31.5	13.7	0.0
100,000	26.8	60.6	12.7	0.0
200,000	18.8	65.6	12.5	3.1
All respondents (total)	45.0	42.6	11.0	1.4

We estimated a multivariate regression using a probit model to explain these stated intentions of respondents. Our model is based on a random utility framework, which assumes that respondents' attempt to maximize their utility when they decide whether to pay for the vaccine at the specified price (McFadden, 1974; Hanemann, 1984). The probability that the respondent will pay for the vaccine is modeled as...

$$\text{Prob[Respondent pays for vaccine]} = \text{Prob}[U_V - U_{NV} > 0]$$
$$= \text{Prob}[\varepsilon_{NV} - \varepsilon_V < a + b\,y - cp + \mathbf{d'Z}]$$
$$= \Phi(a + b\,W - cp + \mathbf{d'Z}); \quad (1)$$

where y is income; p the price of the vaccine; **Z** is a vector of other socioeconomic variables; $a = \alpha_V - \alpha_{NV}$; $b = \beta_V - \beta_{NV}$; $c = \beta_V$; $\mathbf{d} = \delta_V - \delta_{NV}$; V stands for the decision to pay; NV for the decision not to pay for the vaccine; $\varepsilon_{NV} - \varepsilon_V$ is assumed to have a standard normal distribution; $\Phi(.)$ is the cumulative distribution function of the standard normal distribution.

Table 5 presents the names and descriptions of the variables included in the multivariate model. The dependent variable is the probability that a respondent will choose to pay for the hypothetical malaria vaccine. We hypothesize this to be dependent upon the price of the vaccine, the respondent's household income, and the respondent's gender, age, occupation and education level. We also included three dummy variables: (1) whether or not the household had a private water connection; (2) whether the respondent obtained water from a public tap or an alternative source user; and (3) whether the respondent had had malaria before.

The majority of households in our sample were very poor, and we judged that self-reported cash income was not a reliable estimate of real income, in part because so many households relied heavily on subsistence agriculture. We used two proxies for household income. One is a simple count of some selected household assets (W). Ninety-eight percent of the households in our sample did not own a bicycle, 86 percent did not have a sewing machine. Most households did own radios: 45 percent have one radio, 12 percent have two or more. [10] We collected data on the number of goats and pigs owned by households because these are valuable assets in Marracuene. Eighty-three percent of the sample households had no pigs; 89 percent, no goats. Eight percent of all households in the sample had no assets; 43 percent had one asset; 20 percent, two; 11 percent, three; and the remaining 18 percent had four or more. Our second proxy for household income is the number of rooms in the respondent's house.

We expect the price effect to be negative – as the price of the vaccine increases, fewer people should be willing to pay for the vaccine. Income or wealth should have a positive effect: the rich should be more likely to buy the vaccine at all prices than the poor. The effect of formal education is unclear. It is commonly assumed that education would have a positive effect on demand for improved health, perhaps because better-educated people should understand better the epidemiology of the disease and the benefits derived from the vaccine. We consider this line of argument quite problematic. Education also correlates with income.

The effect of gender on the probability that a respondent will agree to pay for the vaccine is also uncertain. Age is likely to have a negative effect, because older people probably feel less confident about their future income and have a lower opportunity cost of time. Occupation is expected to have a positive effect, since it correlates with both income and education.[11] We expect that people who have had malaria before should be more inclined to pay for the vaccine, because they know from experience the consequences of an episode of malaria. There are, however, other equally plausible stories one could tell. For example, it could be that those people who have not had malaria are most afraid of it, particularly in a malaria-endemic area such as Marracuene where everyone must know many people who have had the disease. There could even be a selectivity bias here: those respondents who have not had malaria recently could be those most concerned and they could have taken some precautionary actions to avoid the disease.

The dummy variables for private connection and public tap use try to capture the fact that households that have access to these services live in better conditions than those that use alternative water sources. Households with private connections, for instance, typically live in brick houses in the center of town, where streets are paved, and there is often a steady wind coming from the sea. Malaria is probably less common here than in other parts of town. Because they are less exposed to malaria than other individuals, we expect that respondents with private connections, all else the same, would be less likely to purchase the vaccine than other people. Public tap users should be less willing to pay than those using alternative water sources, for similar reasons.

To assess the robustness of parameter estimates and the results we estimated numerous model specifications to account for different combinations of independent variables. Missing values in the data set complicated the estimation of these models. The wealth variable was available for only 203 of the 282 observations (see Table 6). Therefore, models that included this variable were estimated with a set of observations quite different from those that did not include it. Other variables also had numerous missing values, so that when they were dropped from the model, the data set also changed. This problem precluded a rigorous comparison of the different models using the log-likelihood function (-2 log(L)) and the Akaike Information Criterion (AIC) and Schwartz Criterion (SC) statistics.[12] The large number of missing values also simply precluded the use of several variables in the most general model specification.

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[10] In 1990, there were 42 radios and 3 TV sets per 1000 inhabitants in Mozambique [Mozambique (1994)].

[11] Occupation is measured by a dummy variable that is 1 for factory workers, large traders and civil servants, and 0 for other occupations.

[12] The -2 log(L), AIC and SC statistics are primarily used for comparing different models for the same data. When comparing models, lower values of these three statistics indicate a better model.

Table 5: Names and descriptions of variables used in the probit analysis

Variable Name	Variable Code	Description	Expected Sign
WTP for Malaria Treatment	VMVOTE	Yes or no answer for use of malaria vaccine	
Price	PRICE	Price of malaria vaccine, in 1000 MT	-
Gender	MALE	Gender of respondent (Male = 1)	?
Wealth	WEALTH	Number of assets of household	+
Age	AGE	Age of respondent	?
Education	EDU	Number of years of schooling	+
Occupation	DOC	Dummy for occupation (=1 for factory workers, large traders and civil servants; =0 for the rest)	+
Number of rooms	ROOMS	Number of rooms in the house	+
Source	DSOURCE	Whether primary source is public tap (=1) or alternative source (=0)	
Private Connection	PC	Whether household has a private connection (=1) or not (=0)	+
Malaria Before	MHAD	Whether respondent had had malaria before (=1) or not (=0)	+
Income x Price	WM	Wealth x Price	+

Table 6: Basic descriptive statistics of variables used in probit analysis

Variable	N	Mean	Std. Dev.	Minimum	Maximum
VMVOTE	278	0.46	0.50	0	1
PRICE	282	88.10	68.54	15	200
MALE	278	0.59	0.49	0	1
WEALTH	203	2.94	6.15	0	75
AGE	267	40.40	12.50	17	79
EDU	259	3.50	2.80	0	11
DOC	282	0.30	0.46	0	1
ROOMS	262	1.59	1.04	0	6
SOURCE	281	0.52	0.50	0	1
PC	257	0.26	0.44	0	1
MHAD	269	0.72	0.45	0	1
WM	203	203.00	354.00	0	3750

Table 7 presents the results of five different specifications of the probit model (1). Model (1) includes all the variables listed above; model (4) is the same, except that the wealth variable and the wealth-price cross effect are excluded. In both these specifications, the price of the vaccine has a negative and significant effect. In addition, in model (1) wealth shows a positive and statistically significant coefficient, while the cross effect of price and wealth is negative and significant. Almost all other variables have the expected sign in both models, although none, except Age in model (1), is statistically significant at the 10-percent level. Interestingly, whether or not the respondent had had malaria before or not was found to be not statistically significant in any of the specifications we examined.

Model (2) includes a reduced list of independent variables. Although models (1) and (2) are not directly comparable because the later was estimated with 25 more observations than the former, its statistical significance is higher, and it has almost the same predictive power. The coefficients of the variables included in both models are also very similar. Model (5) presents a reduced form of model (4). In model (5), only the price of the vaccine remains as an explanatory variable. A comparison of models (4) and (5) highlights the importance of price as a determinant of demand for the hypothetical malaria vaccine.

In the rest of the analyses presented in this paper, we will use model (2) as our preferred specification. It states that the probability of an individual deciding to pay for the malaria vaccine is a function of his/her wealth, the price of the vaccine, and of whether his/her household has a private water connection or not. The negative sign of the coefficient for the dummy variable that indicates whether or not the respondent's household has a private water connection suggests that respondents in households that have private connections are less willing to pay for the malaria vaccine than others. As noted, we believe this is because these households may be less vulnerable to malaria than the ones that live in houses without private connections. In addition, some of the household heads living in the center of town are civil servants that would continue to be paid when they are on sick leave due to malaria.

The composite effect of price and wealth has a negative and statistically significant coefficient. The negative sign of this interaction variable implies that wealthier individuals are more price-elastic than poorer ones, i.e., the rich are more price-sensitive than the poor are. This can be seen by re-arranging model (2):

For individuals in households with private connections:

$$\text{Prob[individual pays for vaccine]} = \Phi\,[0.0715 + 0.1679\,W - (0.0055+0.0026W)p] \quad (2)$$

For individuals in households without private connections:

$$\text{Prob[individual pays for vaccine]} = \Phi\,[0.5992 + 0.1679\,W - (0.0055+0.0026W)p] \quad (3)$$

The average number of assets of the households included in the preferred model estimation is 3.1, which, when substituted in the model, gives a coefficient for the price variable not much different from the one obtained in model (2).[13]

We carried out two sets of calculations to estimate the sensitivity of the probability of a respondent indicating his intention to pay for the vaccine with respect to changes in price and wealth. The first consisted of estimating the marginal effects of price and wealth on this probability by using our preferred model specification in the following manner:

Marginal effects of price...

1. For households without a private connection:

$$\partial\text{Prob[individual i decides to pay for vaccine]}/\partial p = (-\,0.0055 - 0.0026\,W)\,\phi[0.5992 + 0.1679\,W - (0.0055 + 0.0026\,W)\,p] \quad (4)$$

and

2. For individuals living in households with a private connection:

$$\partial\text{Prob[individual i decides to pay for vaccine]}/\partial p = (-\,0.0055 - 0.0026\,W)\,\phi[0.0715 + 0.1679\,W - (0.0055 + 0.0026\,W)p] \quad (5)$$

[13] The latter is not much different from the coefficients observed in models (4) and (5), which makes us more confident that our estimates were not seriously biased by the missing data mentioned previously.

Table 7: Multivariate Probit Models: Willingness to Pay for Malaria Vaccine

Variables	Full Model with Wealth (1)	Reduced Model with Price x Wealth (2)	Reduced Model without Price x Wealth (3)	Full Model without Wealth (4)	Reduced Model without Wealth (5)
Constant	1.23 (0.6478)	0.60 (0.24)	0.88 (0.20)	0.46 (0.48)	0.60 (0.13)
Price	-0.0054 + (0.0031)	-0.0055+ (0.0028)	-0.0103⌖ (0.0018)	-0.0094⌖ (0.0016)	-0.0084⌖ (0.0013)
Wealth	0.21♣ (0.09)	0.17♣ (0.07)	0.03 (0.03)		
Price x Wealth	-0.0033♣ (0.0015)	-0.0026♣ (0.0013)			
Private Connection	-0.47 (0.30)	-0.53♣ (0.23)	-0.51♣ (0.23)	-0.20 (0.25)	
MHAD	0.10 (0.22)			0.16 (0.17)	
Source	-0.07 (0.27)			-0.04 (0.21)	
Rooms	0.12 (0.14)			0.0016 (0.1075)	
Male	-0.13 (0.31)			-0.08 (0.24)	
Education	-0.02 (0.05)			0.04 (0.04)	
DOC	-0.014 (0.26)			-0.17 (0.22)	
Age	-0.02 + (0.01)			0.002 (0.009)	
-2logL (unrestricted)	212.2	248.0	248.0	291.9	383.3
-2logL (restricted)	155.9	193.8	198.6	241.7	334.0
Chi-Sq. Stat.	56.3	54.2	49.4	50.1	49.3
Chi-Sq. d.f.	11	4	3	9	1
Chi-Sq. Sig.	0.0001	0.0001	0.0001	0.0001	0.0001
N	154	179	179	214	278
% correctly predicted	83.3	79.5	78.8	78.7	64.9

\+ Statistically significant at 10% level; ♣ Statistically significant at 5% level; ⌖ Statistically significant at 1% level.

Marginal effects of wealth...

1. *For individuals living in households without a private connection*:

$$\partial \text{Prob[individual i decides to pay for vaccine]}/\partial W = (0.1679 - 0.0026\, p)\, \phi[0.5992 + 0.1679\, W - (0.0055 + 0.0026\, W)\, p] \quad (6)$$

2. *For individuals living in households with private connections*:

$$\partial \text{Prob[individual i decides to pay for vaccine]}/\partial W = (0.1679 - 0.0026\, p)\, \phi[0.0715 + 0.1679\, W - (0.0055 + 0.0026\, W)\, p] \quad (7)$$

where $\phi(.)$ is the standard normal density function.

Using expressions (4) to (7), we estimated the marginal effects of price and wealth for several values of these variables (Tables 8a and 8b). From Table 8a we see that the marginal price effect is always negative, and in most cases larger in absolute terms for wealthier people. This is not always the case because in some instances when wealth increases, the value of the density function decreases, overwhelming the price effect.

The marginal wealth effects are large and significant for low to medium price levels (compared to price effects) and negative for medium to high prices. This is because when wealth increases, it affects the probability that an individual would be willing to pay for the vaccine in two ways. The first effect is direct and positive: the malaria vaccine is a normal good and increased income increases demand. The second effect is indirect: increased wealth makes the respondent more price-sensitive. The first effect is stronger at low prices for the vaccine; the second at high prices. It is not clear to us why wealthier individuals should be more price-sensitive than poorer individuals. One possibility is that low-income individuals are more risk averse, and thus the vaccine is more important to them as a way of reducing risk. There is no clear difference between the marginal effects of wealth and price for individuals living in households with and without private connections.

The second procedure involved calculating a value for each respondent in the sample and then determining the average of these values (Griffin and Guilkey, 1993). Again, because individuals in households with and without private connections had different stated intentions, we estimated these probabilities separately for the two groups. These estimates are reported in Tables 9a-c and 10a-c.

In Table 9a, each entry is the average over the 179 individuals in the sample used to estimate the preferred model, with each individual probability estimated by varying the values of p and W. In the base case, the average probability is equal to 0.49 and is obtained as the mean of the estimated probabilities for each individual for their actual values of price and wealth. This value compares with 0.51, which was the actual proportion of individuals who said they would pay for the vaccine in the sample of 179 observations used to estimate the preferred model.[14] We obtained the remaining entries in the Table 9a by increasing each individual's asset holdings and decreasing (by 10,000 MT) and increasing (by as much as 50,000 MT) the value of the price each received. In Tables 9b and 9c, we repeat this exercise for individuals in households without and with private connections, respectively. Note that the probabilities of the former are always higher. Also, households with private connections are greatly overrepresented in our sample. Although 58 households in this subsample of 179 observations that were used in this regression have private connections, in the community less than 100 households out of approximately 6,000 have private connections. Therefore, the probabilities in Table 9a underestimate the proportion of household heads in Marracuene that would be willing to pay for the vaccine at the relevant price and wealth levels.

Tables 10a-c present estimates for the probability of an individual being willing to pay for the hypothetical malaria vaccine for a specified set of price and wealth levels. These estimates are more

[14] It is about 10 percent above the proportion for the entire sample (0.46).

readily comparable to the marginal effects reported in Table 8a-b. They show that the probabilities of being willing to pay for the vaccine are always higher for individuals in households without private water connections, that they fall as price increases, and that they can either increase or fall with wealth depending on the price level. In particular, they indicate that "very wealthy" people are not very likely to pay a high price for the vaccine.

Table 8a: Marginal Effects of Price Changes on the Probability of Buying Vaccine

Households with Private Connections (Wealth - # of assets)

Price (in 1000 MT)	0	1	2	3	4	5	6	7
10	-0,002	-0,003	-0,004	-0,005	-0,005	-0,006	-0,006	-0,006
30	-0,002	-0,003	-0,004	-0,005	-0,006	-0,007	-0,008	-0,008
50	-0,002	-0,003	-0,004	-0,005	-0,006	-0,007	-0,008	-0,009
75	-0,002	-0,003	-0,004	-0,005	-0,006	-0,007	-0,007	-0,008
100	-0,002	-0,003	-0,003	-0,004	-0,004	-0,005	-0,005	-0,005
125	-0,002	-0,002	-0,003	-0,003	-0,003	-0,003	-0,003	-0,002
150	-0,002	-0,002	-0,002	-0,002	-0,002	-0,001	-0,000	-0,000
175	-0,001	-0,002	-0,001	-0,001	-0,000	-0,000	-0,000	-0,000
200	-0,001	-0,001	-0,000	-0,000	-0,000	-0,000	-0,000	-0,000

Households without Private Connections (Wealth - # of assets)

Price (in 1000 MT)	0	1	2	3	4	5	6	7
10	-0,002	-0,003	-0,003	-0,003	-0,003	-0,003	-0,003	-0,003
30	-0,002	-0,003	-0,004	-0,004	-0,005	-0,005	-0,005	-0,005
50	-0,002	-0,003	-0,004	-0,005	-0,006	-0,006	-0,007	-0,008
75	-0,002	-0,003	-0,004	-0,005	-0,006	-0,007	-0,008	-0,009
100	-0,002	-0,003	-0,004	-0,005	-0,006	-0,007	-0,007	-0,008
125	-0,002	-0,003	-0,004	-0,005	-0,005	-0,005	-0,005	-0,005
150	-0,002	-0,003	-0,003	-0,004	-0,003	-0,003	-0,003	-0,002
175	-0,002	-0,003	-0,003	-0,003	-0,002	-0,002	-0,000	-0,000
200	-0,002	-0,002	-0,002	-0,002	-0,001	-0,000	-0,000	-0,000

Table 8b: Marginal Effects of Wealth Changes on the Probability of Buying Vaccine

Households with Private Connections (Wealth - # of assets)

Price (in 1000 MT)	0	1	2	3	4	5	6	7
10	0,057	0,056	0,054	0,051	0,048	0,044	0,039	0,034
30	0,036	0,036	0,036	0,036	0,035	0,034	0,033	0,031
50	0,015	0,015	0,015	0,015	0,015	0,015	0,015	0,015
75	-0,010	-0,010	-0,010	-0,009	-0,009	-0,009	-0,009	-0,009
100	-0,032	-0,031	-0,029	-0,027	-0,025	-0,023	-0,021	-0,019
125	-0,051	-0,046	-0,040	-0,034	-0,029	-0,024	-0,019	-0,015
150	-0,066	-0,055	-0,043	-0,032	-0,023	-0,016	-0,010	-0,006
175	-0,076	-0,057	-0,039	-0,025	-0,015	-0,008	-0,004	-0,002
200	-0,082	-0,054	-0,031	-0,016	-0,007	-0,003	-0,001	-0,000

Households without Private Connections (Wealth - # of assets)

Price (in 1000 MT)	0	1	2	3	4	5	6	7
10	0,049	0,045	0,040	0,035	0,031	0,026	0,021	0,017
30	0,033	0,031	0,030	0,028	0,026	0,024	0,022	0,020
50	0,015	0,014	0,014	0,014	0,014	0,014	0,013	0,013
75	-0,010	-0,010	-0,010	-0,010	-0,010	-0,010	-0,010	-0,010
100	-0,036	-0,036	-0,036	-0,035	-0,034	-0,033	-0,032	-0,030
125	-0,062	-0,060	-0,057	-0,053	-0,048	-0,043	-0,037	-0,031
150	-0,085	-0,079	-0,070	-0,059	-0,048	-0,037	-0,027	-0,019
175	-0,106	-0,092	-0,073	-0,054	-0,037	-0,023	-0,013	-0,007
200	-0,123	-0,097	-0,068	-0,042	-0,023	-0,011	-0,005	-0,002

Table 9a: Simulations departing from observed prices and wealth: Probabilities of paying for malaria vaccine (averages over sample)

	Wealth	Wealth +1	Wealth +2	Wealth +3	Wealth +4	Wealth +5
Price - 10	0.52	0.52	0.52	0.53	0.53	0.53
Price	0.49	0.48	0.48	0.48	0.48	0.49
Price + 10	0.45	0.44	0.44	0.43	0.43	0.43
Price + 20	0.41	0.40	0.38	0.38	0.37	0.37
Price + 30	0.37	0.35	0.34	0.33	0.32	0.31
Price + 40	0.34	0.31	0.29	0.28	0.27	0.26
Price + 50	0.31	0.28	0.25	0.23	0.22	0.21

Table 9b: Simulations departing from observed prices and wealth, households without private connections: Probabilities of paying for malaria vaccine (averages over sample)

	Wealth	Wealth +1	Wealth +2	Wealth +3	Wealth +4	Wealth +5
Price - 10	0.57	0.56	0.56	0.56	0.56	0.56
Price	0.53	0.52	0.52	0.51	0.51	0.51
Price + 10	0.50	0.48	0.47	0.47	0.46	0.46
Price + 20	0.46	0.44	0.43	0.42	0.41	0.40
Price + 30	0.43	0.40	0.38	0.37	0.35	0.34
Price + 40	0.39	0.36	0.33	0.32	0.30	0.29
Price + 50	0.36	0.32	0.29	0.27	0.25	0.24

Table 9c: Simulations departing from observed prices and wealth, households with private connections: Probabilities of paying for malaria vaccine (averages over sample)

	Wealth	Wealth +1	Wealth +2	Wealth +3	Wealth +4	Wealth +5
Price - 10	0.44	0.46	0.46	0.47	0.48	0.48
Price	0.40	0.41	0.41	0.42	0.43	0.43
Price + 10	0.36	0.36	0.36	0.36	0.37	0.37
Price + 20	0.31	0.30	0.30	0.30	0.30	0.30
Price + 30	0.27	0.26	0.25	0.25	0.25	0.24
Price + 40	0.23	0.22	0.21	0.20	0.20	0.19
Price + 50	0.20	0.18	0.17	0.16	0.15	0.14

Table 10a: Simulations varying prices and wealth, complete sample: Probabilities of paying for malaria vaccine (averages over sample)

Price	Wealth					
	0	1	2	3	4	5
10	0.65	0.70	0.75	0.79	0.83	0.86
15	0.64	0.69	0.73	0.77	0.81	0.84
30	0.61	0.65	0.68	0.71	0.74	0.77
50	0.57	0.59	0.60	0.62	0.63	0.65
100	0.47	0.43	0.40	0.36	0.33	0.30
200	0.27	0.17	0.10	0.05	0.02	0.01

Table 10b: Simulations varying prices and wealth, households without private connections: Probabilities of paying for malaria vaccine (averages over sample)

Price	Wealth					
	0	1	2	3	4	5
10	0.71	0.75	0.80	0.83	0.87	0.90
15	0.70	0.74	0.78	0.82	0.85	0.88
30	0.67	0.70	0.73	0.76	0.79	0.81
50	0.63	0.64	0.66	0.67	0.68	0.70
100	0.52	0.48	0.45	0.41	0.38	0.34
200	0.31	0.20	0.12	0.06	0.03	0.01

Table 10c: Simulations varying prices and wealth, households with private connections: Probabilities of paying for malaria vaccine (averages over sample)

Price	Wealth					
	0	1	2	3	4	5
10	0.51	0.56	0.62	0.67	0.72	0.77
15	0.50	0.55	0.60	0.65	0.69	0.74
30	0.46	0.50	0.54	0.57	0.61	0.64
50	0.42	0.44	0.45	0.47	0.48	0.50
100	0.32	0.29	0.26	0.23	0.20	0.18
200	0.15	0.08	0.04	0.02	0.01	0.00

6. Comparisons of Contingent Valuation Estimates with the Cost-of-Illness Approach

A common method of estimating the economic value to an individual of preventing an illness such as malaria is to calculate the private cost of illness (COI) as the expected value of the direct and indirect losses an average individual might anticipate *ex ante*. This can be estimated by multiplying the risk of contracting the disease by the monetary losses that would be suffered if the illness occurred. The costs of illness are typically assumed to consist of two main components: (1) the direct costs of medical care and supplies (including any transportation costs to reach a health care facility); and (2) the indirect costs associated with the lost wages of the infected person and any other individuals who must stop their work to take case of the person infected with malaria. The direct medical costs in Marracuene from an episode of malaria are minimal due to the subsidized services and medicines. Moreover, we do not have data on the time spent by caregivers, and thus cannot include these costs in the COI estimate].

Data collected in Marracuene can be used in the following manner to make some simple COI calculations based on the indirect productivity losses to the patients themselves. The average respondent in the sample had 1.2 episodes of malaria over the last two years. Assuming a Poisson distribution of episodes, the expected number of times an individual would contract malaria per year is 0.6. The average length of a malaria episode among the respondents in the sample was 10 days; the median value is one week. Assume that an individual loses one week's wages. The national minimum wage in Mozambique in November 1994, was 107,000 meticais per month. The actual minimum wage of laborers employed in the textile factory in Marracuene was 165,000 meticais per month (US$26). Many subsistence farmers in Marracuene did not make even the national minimum wage, but other people make the minimum wage at the factory and are able to supplement these earnings with other work. If we assume that the lost wages in Marracuene are valued at the national minimum wage, the expected value of an individual's loss from malaria in Marracuene is...

Expected annual loss = [expected number of episodes][lost weekly wages] (8)
= [0.6] [107,000 meticais / 4]
= 16,000 meticais (US$2.47)

If it is assumed that the opportunity cost of wages lost is valued at the minimum wage at the textile factory in Marracuene, the expected value of an individual's loss is...

Expected annual loss = [expected number of episodes][lost weekly wages] (9)
= [0.6] [165,000 meticais / 4]
= 25,000 meticais (US$3.85)

An alternative estimate for the economic value of the vaccine may be obtained from the random utility model used to derive our probit model. This estimate would be the value that makes the average individual indifferent between using and not using the vaccine; that is the value that equals the expected utilities of paying or not paying for the vaccine. This value is given by

Willingness to Pay for Vaccine = (a + b y + **d'Z**)/c (10)

and substituting the estimates in the preferred model results in

WTP for Vaccine = [0.5992 + 0.1679 W - 0.5277 PC] / [0.0055+0.0026W] (11)

We used two different ways to calculate the average willingness to pay for an individual in our sample. First, we used our econometric model to calculate the WTP for a "typical" respondent, i.e., one with an average number of assets, does not have a private connection, and is charged the average price for the malaria vaccine. We repeated this exercise for a "typical" individual with a private connection. Second, we used the socioeconomic characteristics of each respondent in our sample, and calculated the WTP for each of our respondents, using our preferred econometric model. We then took the average of these values. Again, we did the calculation separately for households with and without private connections.

The contingent valuation estimates of average household willingness to pay for the malaria vaccine obtained in this fashion are reported in Table 11. Note that they are substantially higher than the simple COI estimates. The mean economic value of the vaccine obtained from the CV data, is in the range of 70 to 74 thousand meticais, approximately three times higher than the larger COI estimate presented above. The estimates of willingness to pay for the vaccine for households without private connections based on the CV data are about 76 percent more than for households with private connections.

In fact, there are three main reasons why one would expect the estimates from the COI approach to be lower than the estimates of the economic value of a vaccine based on responses from the contingent valuation survey. First, the COI approach ignores the disutility of the pain and anguish suffered by the individual. Second, the COI approach assumes that the individual is risk neutral; in fact, one would expect low-income individuals such as respondents in Marracuene to be strongly risk averse. Risk-averse individuals would be willing to pay more for the malaria vaccine than risk-neutral individuals. Third, the COI estimates do not include the economic losses of caregivers.

Table 11: Willingness to Pay for Malaria Vaccine (in MT 1,000)

	All Households			Households with PC			Households without PC	
Variable	All Data	Data Used in Regr.		All Data	Data Used in Regr.		All Data	Data Used in Regr.
Average Values of Wealth and Dummy for Private Connection								
Wealth (# assets)	2.94	3.11		4.76	4.83		2.27	2.29
PC	0.26	0.32		1	1		0	0
Willingness to Pay (in 1,000 MT)								
WTP of Average Respondent	72.9	70.3		49.0	49.1		86.4	86.3
Average of Individuals' WTP	74.0	74.0			39.6			90.5

Note that the CV estimate is based on an approximation of the total economic benefits of a malaria vaccine to the sample of respondents divided by the number of respondents. The 21 percent of the sample respondents who agreed to pay 200,000 meticais for the vaccine, account for over fifty percent of the sample average of 75,000 meticais. In other words, the contingent valuation results suggest that the majority of the economic benefits from a malaria vaccine would accrue to the 21 percent of the population that we estimate would agree to pay 200,000 meticais. From the opposite perspective, avoiding the risk of malaria has a very low value to a substantial minority of the sample respondents. For example, 23 percent of the respondents who received the price of 15,000 meticais (US$2.30) were not willing to pay this amount. This is consistent with our observation that there were dual labor markets in Marracuene, and the opportunity cost of time to many subsistence farmers is very low.

7. Summary and Conclusions

The results from this contingent valuation study suggest that it is possible to ask very low-income respondents in rural Mozambique questions about a hypothetical malaria vaccine and obtain what appear to be reasonable answers.[15] The results of our analysis confirm that respondents listened to the price information in the contingent valuation scenario and that their answers depended upon the price they received.

The estimates of average household willingness to pay to avoid the (high) risk of contracting malaria for one year based on the contingent valuation data are approximately US$14, equivalent to about seven chickens in the local economy at the time of the CV survey, or 1.5 beers a month. This may strike observers in industrialized countries, as extremely low, but in fact a payment of this magnitude would constitute a substantial commitment of a household's resources in Marracuene. It is roughly equivalent to what most households indicated they are willing to pay for improved water services from public taps in Marracuene. These findings indicate that households in Marracuene place quite a high value on malaria prevention. It should be emphasized that these results are for households living in a community where the prevalence of malaria is high, and residents were relatively well-off compared to other parts of Mozambique. These findings may not be generalizable to poorer communities or to communities where prevalence is lower.

[15] This evidence that the contingent valuation method can be applied in Africa is consistent with other findings (Whittington et al., 1992, 1993).

The estimates of average household willingness to pay for the malaria vaccine based on the contingent valuation data are on the order of three to four times higher than the estimates based on the simple COI approach. For some health economists, this result may confirm their belief that the contingent valuation method is unreliable and overestimates economic benefits because respondents are not disciplined by an actual budget constraint. It is important to emphasize, however, that economic theory shows that the contingent valuation estimates should be higher than the productivity loss estimates, and the magnitude of this difference is unknown (Harrington and Portney, 1987).

The methods presented in this paper to estimate the economic benefits of a malaria vaccine can also be used to estimate demand for vaccines against other diseases (Whittington et al., 2002). Future contingent valuation studies of demand for malaria (and other) vaccines can improve upon the research design used in this study in a number of ways. First, with larger samples both the duration and the efficacy of the vaccine can be systematically varied across respondents in order to better understand how willingness to pay changes as a function of these characteristics of the vaccine. Second, this study focused on the demand of adults for a malaria vaccine. Adults may chose not to purchase a vaccine for themselves but want to purchase the vaccine for their children (Cropper et al., 2003). The study of household demand for vaccines and the intrahousehold allocation of vaccines is a promising area for future research.

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Appendix: An Overview of the Malaria Situation in Mozambique

1. Prevalence

Health statistics for Mozambique reveal that in the early 1990s malaria was the most common cause of admission for children and adults in rural and general hospitals (Mozambique, 1994:20-21).[16] As shown in Table A1, in 1992 malaria was responsible for 22 percent of all admissions and deaths of children in level II hospitals in Mozambique. Adults suffer from a larger number of diseases than children. The five most significant diseases accounted for just 20 percent of the total number of admissions and deaths. As with children, malaria is the most important cause of hospital admissions for adults and ranks as the third cause of adult deaths in rural and general hospitals.

Table A1: Distribution of Admissions and Deaths in Rural and General Hospitals in Mozambique, 1992 (%)

Disease	Adults		Children	
	Admissions	Deaths	Admissions	Deaths
Malaria	7.2	5.0	22	22
Tuberculosis	3.6	5.2	1	N.R.
Diarrhea	3.6	2.8	10	9
Anemia	3.4	5.2	8	11
Pneumonia	2.2	1.8	12	9
Undernourishment	N.R.	N.R.	15	15
Measles	N.R.	N.R.	3	N.R.

N.R. -- Not reported.
Source: Mozambique, Informação Estatística Anual -1992, Ministério da Saúde, August 1994.

Table A2 shows the death rates (no. of deaths divided by no. of cases) for the most frequent diseases affecting patients admitted in rural and general hospitals. For both adults and children, death rates are higher for anemia and tuberculosis than for malaria. Malaria ranks third among children and fifth among adults. It is somewhat surprising that death rates are higher for adults than for children, especially for pneumonia. For diarrhea, this fact is likely to result from misclassification of cholera and dysentery cases among adults as regular diarrhea cases. For malaria, the higher death rates for adults than children probably result from the different criteria adopted for hospital admission. Adults are only being admitted in critical situations, whereas children are admitted more frequently.

More detailed research studies support the conclusion from the hospital admissions data that malaria is one of the most serious health problems facing Mozambique. Baez and Blanco (1994) show that malaria was the most common disease among children in the Provincial Hospital of Chimoio over the period July 1991 to April 1994, accounting for 34.1 percent of hospital admissions. Malaria was also responsible for 15.5 percent of deaths, with a death rate of 5.7%, ranking third as a cause of death among children (undernourishment and pneumonia, with 28.5 and 15.8 percent of the cases, respectively, were the two major causes of deaths). They observe further that while the cases of undernourishment showed a decline, dropping from 24.3 percent of the cases in 1992 to 17.1 percent in 1993 and 6.1 percent in 1994, the opposite happened to malaria. The malaria cases as a percent of total admissions increased from 25.2 percent in 1992, to 35.9 percent in 1993, and to 56.6 percent in 1994.

[16] In 1994 the health sector in Mozambique was structured as a four-tier referral system going from health posts and centers in level I to Maputo's Central Hospital in level IV. Rural and general hospitals form level II and provincial hospitals level III.

Table A2: Death Rates of Main Diseases in Rural and General Hospitals, 1992 (%)

Disease	Children	Adults
Malaria	6.1	7.0
Tuberculosis	7.6	14.2
Diarrhea	5.4	7.9
Anemia	8.4	15.9
Pneumonia	4.6	9.1
Undernourishment	5.8	N.R.
Measles	5.0	N.R.

N.R. -- Not reported.
Source: Mozambique, Informação Estatística Anual -1992, Ministério da Saúde, August 1994.

Martinenko, Murure, Dgedge, Barreto and Albuquerque (1994) examined the cases of malaria among children in the Central Hospital of Maputo from January 1989 to July 1993. They concluded that of the 22,528 registered inpatients due to *P. Falciparum*, 84 percent were registered in the first half of the year (including cases of acute, associated and cerebral malaria). The proportions of acute and cerebral malaria increased progressively in the first and second quarters, and then began to decline in the third quarter. The hospital death rate was on average 3.6 percent, ranging from 2 percent for acute malaria to 12.5 percent for cerebral malaria. The mean age of child inpatients with cerebral malaria was significantly higher than that for children with acute and associated malaria.

In a study of malaria incidence in delivering mothers in Maputo, Bergstrom et al. (1993) report malaria infection in 17 percent of their sample of 202 delivering mothers.

2. Evidence regarding drug resistance

Resistance of *Plasmodium falciparum* to various drug regimes is both prevalent and increasing throughout tropical Africa, including Mozambique (Schapira, 1989). The first cases of chloroquine-resistant malaria in Mozambique were detected in May 1983 and were apparently brought into the country from Angola and Tanzania (Franco et al., 1984). Tables A3 and A4 provide a summary of results from different studies about the resistance of *Plasmodium falciparum* to chloroquine in Mozambique over the period 1970-87.

Schapira and Costa (1988) carried out trials of two different malaria prophylaxes in southern Mozambique in 1985 and 1986. They found that chloroquine had no effect on parasite rates or densities in Maputo, and concluded that chloroquine dosage of 5 mg/kg was probably useless against *Plasmodium falciparum* given the level of chloroquine-resistance found in Maputo in 1985.[17] In a randomized study of the effect on *Plasmodium falciparum* of four treatment regimes on 200 asymptomatic school children in Maputo, Schapira and Schwalbach (1988a) concluded from *in vivo* tests that 94 percent of the infections were resistant to chloroquine, 76 percent to amodiaquine, and 16 percent to sulfadoxine-pyrimethamine (*Fansidar*). They found that the cure rate with amodiaquine plus sulfadoxine-pyrimethamine was 100 percent, but noted that this was not statistically different from the effectiveness of sulfadoxine-pyrimethamine alone. In a follow-up report, Schapira, Bygbjerg, Jepsen, Fachs and Bentzon (1988) report increasing resistance of *Plasmodium falciparum* to treatment with sulfadoxine plus pyrimethamine.

Dgedge and Fumane (1994) made an *in vivo* assessment of the sensitivity of the *P. falciparum* to chloroquine with 742 pregnant women in a health center in the province of Tete, during the first semester of 1994. Of these 742 women, 72 (9.6 percent) were infected, and were treated with chloroquine (dose of 25mg/kg) and observed 2, 7 and 14 days after a 3-day treatment at the health care

17 Schapira and Costa also concluded that it was doubtful whether chloroproguanil would retain any efficacy if employed over a long period.

unit. Patients were considered to be malaria resistant if on the second day they had more than 25 percent of the initial parasitemy, or if parasites were found on the seventh or fourteenth days. The chloroquine treatment was considered to have failed if from the seventh to the fourteenth day the auxiliary temperature was above 37.4 ^{O}C in the presence of parasitemy. Twenty-two percent of the 72 pregnant women were found to be chloroquine resistant. Chloroquine resistance was found to decrease with age. It was 34.8 percent in the 20-24-year-old group and 13.8 percent for women with 30 or more years of age. The effectiveness of the chloroquine therapeutics was very high (98.7 percent). Only one woman had fever and parasites during the controls of days 7 and 14.

In a study conducted in health centers in Boane, Xai-Xai, Tete and Montepuez, during the first half of 1994, Dgedge, Streat, Mabubda, Fumane, Mavale and Gomes (1994) studied 1093 outpatients to assess the sensitivity *in vivo* of *P. falciparum* to chloroquine. Patients were treated with chloroquine (dose of 25mg/kg) and observed 2, 7 and 14 days after a 3-day treatment at the health care unit. Patients were considered to be malaria resistant if on the second day they had more than 25 percent of the initial parasitemy, or if parasites were found on the seventh or fourteenth days. The chloroquine treatment was considered to have failed if from the seventh to the fourteenth day, the auxiliary temperature was above 37.4 ^{O}C in the presence of parasitemy. The following rates of chloroquine resistance were observed: Boane, 38.4 percent; Xai-Xai, 45.2 percent; Tete, 31.2 percent; and Montepuez, 32.4 percent. For the 1093 patients, resistance decreased with age. For those with less than five years it was 42.7 percent, while for those with more than 20 years it was 16.5 percent (χ^2 = 36.08, p<0.001). The types of resistance were: R1, 18 percent; R1/R2, 11.6 percent; and R3, 7.8 percent. The effectiveness of the chloroquine therapeutics was Boane, 78.4 percent; Xai-Xai, 92.1 percent; Tete, 98.6 percent; and Montepuez, 98.5 percent. For those with less than 15 years, effectiveness was around 90 percent, for those with more than 15 years, 97 percent.

Thompson (1994) compared the effectiveness of chloroquine versus sulfadoxine-pyrimethanine in the treatment of *Plasmodium falciparum* in the health post of Fasol, in Matola. Patients were initially submitted to the Saker-Solomos test and those in which the presence of chloroquine was detected were excluded from the sample. Sixty-seven patients were treated with sulfadoxine-pyrimethanine and 46 with chloroquine. Overall resistance to sulfadoxine-pyrimethanine was 11.9 percent, while that to chloroquine was 58.7 percent, with equal levels of RIII, early RI/RII, and late RI in this group. Whereas chloroquine only caused a reduction of the geometric mean of the parasite density of the positive of 13 percent between days 0 and 14, sulfadoxine-pyrimethanine induced a 90.1 percent reduction. Chloroquine showed an effectiveness of clinic cure of 93.7 percent and sulfadoxine-pyrimethanine of 100 percent.

Dgedge et. al. (1994) assessed the effectiveness of a weekly and selective quimioprophylaxy with Dapsona-pyrimethanine (Malopin) in the prevention and control of an epidemic surge of malaria. The study was carried out in the outskirts of the city of Xai-Xai from February to July 1993, with the weekly administration of Malopin. A total of 5744 people were studied, 3063 in the intervention area and 2681 in the control area. In the intervention area Malopin was given to a selected group of 2- to 9-year-old children. In the control area no Malopin was given. In the intervention area malaria incidence was lower in the group that did the quimioprophylaxy (54.7/1000/six months) than in the control area (119.7/1000/six months) (RR=2.19, 95% confidence interval 1.5-3.1). They also observed a lower incidence of malaria in the intervention area (43.7/1000/six months) than in the control area (44.3/1000/six months). The proportion of malaria cases in the health post was lower for the intervention area (29.5 percent) than in the control area (39.7%) (RR=1.19 95% confidence interval 1.05-1.30). The number of clinic cases of malaria showed a tendency to fall in the intervention area and to increase in the control area (χ^2 = 9.04 for tendency, p=0.002).

Table A3: Tests *in vivo* with chloroquine in Mozambique, 1970-87, with patients and non-selected bearers.

Year	Source	Area	Chloroquine mg/kg	Population	Duration of Test (days)	n	S	R	RIt	RIp	RII	RIII
1970	Wolfensberger (1970)	Chicumbane	25	Patients	28	60	56	4**	4**			
1981	Mozambique (1981)	Chókwè	5	Students	14	17	17					
			10	Students	14	54	54					
			25	Students	14	36	36					
1981	Mozambique (1981)	Chókwè	10	Students	14	9	9					
			25	Students	14	8	8					
1983	Joia (1983) [a]	Moatize	10	Students	10	30	30					
			25	Students	10	17	17					
1983	Schwalbach et al. (1985)	Nguri (Chai)	10	Students	14	53	43	10				
			25	Students	14	10	10					
1983	Mozambique (1985a)	Nampula	10	Students	14	51	46	5				
			25	Students	14	33	26	7		4	3	
1984	not reported	Maputo	25	Students	14	314	300	14		14		
1985	Mozambique (1985a)	Nampula	10	Students	7	7	5	2				
			25	Students	7	8	8					
1985	Mozambique (1985b)	Quelimane	10	Students	7	13	6	7				
			25	Students	14	14	5	9		8	1	
1985	Mozambique (1986)	Pemba	10	General	7	5	4	1				
			25	Students	14	30	25	5		5		
1985	Schapira et al. (1985)	Maputo	25	Students	14	13	4	9		8	1	
1986	Schapira and Schwalbach (1988a)	Maputo	25	Students	28	33	2	31	7	20	3	1
1986	Chambule (undated) [b]	Mecanhelas	25	Students	7	46	31	15				
1986	Gomes and Celestino (und.) [c]	Tete	25	Students	14	13	6	7		0	5	2
1987	Schapira (undated) [d]	Beira	25	Students	14	14	4	10		7	1	2

a - H. Joia, Relatório sobre a sensibilidade do P. falciparum à cloroquina. Método *in vivo*. Conducted in Moatize, Tete Province, June 1-19, 1983;
b - J. Chambule, unpublished results; c - A. Gomes and B. Celestino, unpublished results; d - A. Schapira, unpublished results.
Source: Schapira and Schwalbach (1988b).
Note.: ** The author of this study interpreted these 4 cases as being patients re-infected.
[Note: Results were classified according to WHO criteria, i.e., RI defined as recrudescence up to Day 14 and late RI as recrudescence after Day 14. In case of a fourteen-day duration, "S" may mean Sensitive or late RI.]

Table A4: Results from "micro" *in vitro* tests to assess the sensitivity of P. f. to chloroquine in Mozambique, 1984-87.

			Result *in vitro*, n		Classification *in vitro*		MIC, µmol/l of blood							
Year	Source	Area	Population	n	S	R	0,2	0,4	0,8	1,14	1,6	3,2	6,4	>6,4
1984	Schapira (undated) [a]	Maputo	Patients	3		3		2	1					
1985	Schapira et al. (1985)	Maputo	Students	13	2	11			1	1	1	4	5	1
1985	Mozambique (1985) [b]	Maputo	General	50	11	39	1	1	7	2	7	18	13	1
1985		Maputo	(Total)	63	13	50	1	1	8	3	8	22	18	2
1985	Mozambique (1985a)	Nampula	Students	10	3	7			1	2	3	4		
1985	Mozambique (1985b)	Quelimane	Students	13	6	7		2	3	1		4	3	
1985	Mozambique (1986)	Pemba	Students	20	18	2	8	7	2	1		1		1
1986	Schapira and Schwalbach (1988a)	Maputo	Students	77	11	66		4	2	5	7	17	30	12
1986	Schapira (undated) [a]	Xai-Xai	Students	33	12	24	2	3	4	3	6	11	4	
1987	Schapira (undated) [a]	Beira	Students	14	2	12		2		1	3	4	4	

a - A. Schapira, unpublished results.

b - Mozambique, Instituto Nacional de Saúde, Inquérito sobre malária resistente em Maputo Cidade, 1985, unpublished.

Distribution of tests per value of MIC (= minimum concentration that completely inhibits the formation of schizonts. A MIC value ≥ 1.6 µmol/l is indicative of resistance.

The infection is considered sensitive (S) when the assexuated parasites disappear before Day 7 and do not reappear in the following 21 days. There is resistance of degree RI when the parasites are absent during two consecutive days before Day 7, but present in Day 7, or when they are absent in Day 7, reappearing during the following 28 days. In other cases, in which the parasites are present in Day 7, there is resistance of degree RII or RIII. If the parasitemy is reduced during the 48 hours following the beginning of treatment, up to 25 percent or less than the initial, it is case of RII. Otherwise it is RIII.

Casimiro and Dgedge (1994) carried out a study to assess the resistance of *P. Falciparum* to chloroquine in the Provincial Hospital of Lichinga in 1992-93. They examined 155 children with ages ranging from 0 to 7 years that had non-serious malaria. Patients were treated with chloroquine (dose of 25mg/kg) and observed 7 and 14 days after a 3-day treatment in the health care unit. Patients were considered malaria resistant if parasites were found in the patient between days 7 and 14. The chloroquine treatment was considered to have failed if from the seventh to the fourteenth day the axiliary temperature was above 37.4 ^{O}C in the presence of parasitemy. The rate of chloroquine resistance was found to be 11 percent. Resistance was higher in children from 2 to 5 years of age (14.7 percent). In children with less than 2 years of age it was 8.6 percent, and for children with more than 5 years, 9 percent. The effectiveness of the chloroquine therapeutics was 96.7 percent.

Dgedge, Thompson and Hogh (1994) assessed the sensitivity *in vivo* of the *P. falciparum* to sulfadoxine-pyrimethanine in 463 patients that had been found to be chloroquine-resistant malaria. The study was carried out in a health center in Maputo, from January to October 1993. Patients were observed 7, 14 and 28 days after a single-dose treatment with Fansidar (sulfadoxine 25-30 mg/kg + pyrimethanine 1.25-1.50 mg/kg) given at the health care unit. Resistance to Fansidar was defined as the presence of parasitemy during any of the controls. The Fansidar therapeutics was considered to have failed if the auxillary temperature exceeded 37.4 ^{O}C and parasites were present at any time of the control of patients. The rate of resistance to Fansidar was 4.3%, being 5.4% for children 5-years-old or less, and 2.3% for adults with 20 or more years of age. The levels of resistance fluctuated during the study period, with highest levels concentrated in the February-April period, when transmission is also highest. The effectiveness of the Fansidar therapeutics was 99.3 percent.