The Economic Burden of Malaria

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Abstract

Malaria and poverty are intimately connected. Controlling for factors such as tropical location, colonial history, and geographical isolation, countries with severe malaria had income levels in 1995 only 33% of countries without malaria, whether or not the countries were in Africa.

The high levels of malaria in poor countries are not mainly a consequence of poverty. Malaria is very geographically specific. The ecological conditions that support the more efficient malaria mosquito vectors primarily determine the distribution and intensity of the disease. Intensive eradication efforts in the most severely affected countries have been largely ineffective. Countries that have eradicated malaria in the past half century have all been subtropical or islands. These countries' economic growth in the five years following eradication has almost always been substantially higher than growth in their region.

Cross-country regressions for the 1965-90 period confirm the relationship between malaria and economic growth. Taking into account initial poverty, economic policy, tropical location, and life expectancy among other factors, countries with severe malaria grew 1.3% lower per year, and a 10% reduction in malaria was associated with 0.3% higher growth per year.

The paper concludes with speculation about the mechanisms that could cause malaria to have such a large impact on the economy, including the possibility that the effects attributed to malaria are really the result other unmeasured tropical diseases.

Poverty and malaria

Malaria and poverty are intimately connected. As Nobel Laureate in Medicine T.H. Weller (1958: 497) noted, "It has long been recognized that a malarious community is an impoverished community." Weller could have said the same for malarious countries. Malaria is most intractable for countries in the poorest continent, Africa. The only parts of Africa free of malaria are the northern and southern extremes, which have the richest countries on the continent. India, the country with the greatest number of poor people in the world, has a serious malaria problem. Haiti has the worst malaria in the Western Hemisphere, and it is the poorest country in the hemisphere.

Malaria risk has always been very geographically specific, as shown in Figure 1. Severe malaria is confined to the tropical and subtropical zone. Poverty is also geographically specific. As shown in Figure 2, poor countries predominate in the same regions as malaria. Almost all of the rich countries are outside the bounds of malaria risk.

Take the 150 countries with populations over one million in 1995, which account for over 99 percent of the world's population. Forty-four of the 150 countries, or 29 percent, have severe malaria.[1] Thirty-five of these 44 countries are in Africa. The average purchasing-power parity GDP per capita in 1995 for the malarial countries was $1,526, compared to an average income of $8,268 in the countries without severe malaria, more than five times higher.[2] Ranking the 150 countries by income per capita, all but three of the 44 countries with severe malaria are in the bottom half of the ranking. The exceptions are Oman and Gabon, ranked 34th and 41st, which owe their wealth to oil, and the Philippines, which is on the cusp with a rank of 74th. Of the 119 poorest countries, all but twelve have some incidence of malaria or are recovering from socialism. The richest 31 countries are entirely free of malaria.

Not only are malarial countries poor, but economic growth in malarial countries over the past quarter century has been dismal. Growth of income per capita from 1965 to 1990 for countries with severe malaria has been 0.4% per year, while average growth for other countries has been 2.3%, over five times higher.[3] More than a third of the countries with severe malaria (11 out of 29) had *negative* growth from 1965 to 1990.

The question is whether these dramatic correlations mean that malaria *causes* poverty and low growth. We will address this question in three ways. First, we consider the correlation of malaria with income levels after controlling for other factors that are likely to affect the world

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[1] Severe malaria is defined as having a malaria index greater than 0.5. The malaria index for a country is the fraction of the population living in areas of high malaria risk in 1994 times the fraction of malaria cases in 1990 that are of the malignant *P. falciparum* species (from WHO 1992). If *P. falciparum* affected separate land areas from other malaria species (which it does not), this index would be the percent of the population at high risk of *falciparum* malaria. The percent of the population living in areas of high malaria risk in 1994 was calculated using GIS software from a digitized WHO (1997) map of the world distribution of malaria (shown in Figure 2) and a detailed database of world population distribution in 1994 (Tobler and others, 1996).
[2] The 1995 PPP GDP data are from World Bank (1998), supplemented by CIA (1996, 1997) for countries without World Bank data.
[3] The data for GDP growth from 1965 to 1990 for 95 countries are from the Penn World Tables, Mark 5.6 (Summers and Heston, 1994).

distribution of income such as geography, history, and policy. Second, we discuss the determinants of malaria risk. Unlike other important diseases in poor countries caused by deficient living conditions, like diarrhea, tuberculosis, and schistosomiasis, malaria is not a direct result of poverty; its extent and severity are largely determined by the climate and ecology. Third, we explore the impact of malaria on subsequent economic growth. This provides the most direct evidence on the continuing importance of malaria as a cause of poverty.

Malaria and Income Levels

The coincidence of severe malaria and low incomes could be due to many factors besides malaria itself. It could be a general effect of the tropics, caused by poor soils, low agricultural productivity, or tropical diseases other than malaria. It may capture geographical trade barriers, since many malarial countries are landlocked and far from the major centers of world trade. It could be an accident of history. Many malarial countries were colonies until recently, and the misfortunes of colonization may linger, keeping incomes low. Malaria could simply be a proxy for Africa, which may be poor for other reasons such as weak institutions, poor economic policies, or ethnic conflict.

There are strong geographical patterns to income levels around the world.[4] As shown in regression 1 of Table 1, just four geographical variables account for almost half the variation in GDP per capita income levels in 1995. A country's accessibility to the coast, measured by the share of the population within 100 kilometers of the coast, is an important indicator of success in foreign trade and integration into the global economy, and hence related to high income levels. Another measure of accessibility, the minimum distance to the core world markets (New York, Rotterdam, and Tokyo), is inversely related to higher incomes. Thirdly, resource deposits, proxied by the log of hydrocarbon reserves per person, are higher in wealthier countries. Lastly, the tropics, measured by the percentage of a country's land area in the geographical tropics, is much poorer than the rest of the world. The "penalty" for being tropical was –0.57, signifying that tropical areas had only 57% (=exp(-0.57)) of the per capita income of non-tropical areas controlling for other factors.

The next three regressions in Table 1 add the malaria index to the geographical correlates of income per capita in three different years, 1950, 1990, and 1995.[5] The malaria index has a strong negative association with income levels after controlling for the other four geographical factors. Malaria's coefficient increases from 1950 to 1995, suggesting that if anything, malaria has become more important for explaining income levels over time. The association of income with malaria dominates the association with the tropics, which loses statistical significance in the regressions. The coefficient on malaria of -1.08 in 1995 implies that malarial countries have a per capita income only 33% as high as non-malarial countries.

[4] See Gallup and Sachs (1998) for a wider investigation of the role of geography in economic development, and more detailed explanation of the variables used in this section.
[5] The data for PPP GDP per capita in 1950 and 1990 in Table 1 are from Maddison, 1995. The PPP GDP per capita data for 1995 are as in footnote 2.

Regression 5 includes indicators for former colonies, and socialist countries in the post-war era. These new explanatory variables are strongly associated with lower income levels, but taking them into account does not substantially alter the correlation of malaria with low incomes. Regression 6 adds a measure of economic policy, trade openness in the 1965 to 1990 period, and an index of the quality of government institutions. Malaria's association is still unaffected, but the socialist and colony variables lose their significance. If malaria is excluded from this regression, income levels are significantly lower in countries that have been colonized, which suggests that the economic weakness of countries with malaria might have been a factor in their colonial subjugation.

The final regression in Table 1 excludes the sub-Saharan African countries. Malaria has just as strong association with poverty outside of Africa as for the whole world. Malaria is clearly distinguishable from other problems faced by Africa.

Geography, history, and policy all have clear correlations with income levels, but taking them into account does not alter the pattern of lower incomes in malarial countries. The association of malaria with poverty seems to be more than just a mask for other plausible causes of low income.

Cause or Effect?

Malaria is prevalent in the poorest countries. Could this be a consequence, rather than a cause, of poverty? Many other serious diseases predominantly found in poor countries clearly *are* a consequence of poverty, caused by inadequate sewage treatment, unsafe drinking water, poor hygiene, or substandard housing. Malaria, though, does not follow this pattern – it's severity, and the difficulty in eradicating it, are determined mainly by climate and ecology.

Certain countries with very high incomes still face serious malaria problems due to their geographical location. Oman, with an income per capita of almost $10,000, has severe malaria throughout the country except in remote areas of high altitude and desert. United Arab Emirates, next door with one of the highest income levels in the world, also has been unable to eradicate malaria.

Successful malaria eradication through vector control requires a well-run organization and financial resources. The determining factor in where malaria has been eradicated in the post-war era has not been institutional or financial, though. It has been the susceptibility of malaria and the vector to control. Figure 1 shows that malaria eradication since 1946 has only occurred in subtropical regions and certain islands where it foothold is much weaker.

Besides climatic differences, the world distribution of *Anopheles* mosquitoes, the malaria vectors, have a major impact on malaria prevalence and severity. Vectorial capacity is a measure of the efficiency with which mosquitoes carry malaria from one human to another, an estimate of the number of secondary cases of malaria generated by one primary case. The vectoral capacity of different species of *Anopheles* varies by orders of magnitude. By far the most efficient vector, *Anopheles gambiae*, is exclusively found in sub-Saharan Africa.

Vectorial capacity has a major impact on the feasibility of controlling or eradicating malaria in a region. Consequently, malaria eradication through vector control has been orders of magnitude more difficult in sub-Saharan Africa. According to a recent expert committee report: "The epidemiology of malaria is driven by the dynamics of the mosquito vectors. Thus, 90% of the world's malaria is in Africa because it is home to the three most effective vectors." (NIH, 1997, p.12) Not only do the mosquito species determine the intensity of transmission, but they also affect the mix of malaria between the malignant *P. falciparum*, and the less severe *P. vivax*, *P. malariae*, and *P. ovale*. Africa is also the only major region of the world where *falciparum* malaria predominates.

Malaria control in sub-Saharan Africa has been a non-starter. There has been no successful malaria control outside of the temperate southern tip, the controlled environment of some mining camps, and a few islands. In response to the failure of WHO vector control projects in Cameroon, Nigeria, and elsewhere in Africa in the 1960s, the WHO sponsored an intensive malaria control and research project in the district of Garki, Nigeria. No resources, manpower, or institutional support was spared. Over the course of seven years, WHO and the Nigerian government spent more than $6 million to try to eradicate malaria in 164 villages and compare the changes to control villages. Insecticide spraying of every hut at least every 10 weeks during the course of the study had an average coverage of 99%. A third of the villages were also given mass drug administration as a prophylaxis against malaria.

The man-biting rate of mosquitoes in the Garki villages was reduced by 90% from their pre-study level, but despite this huge reduction in mosquito density, there was no significant change in the parasite rate among the villagers. The control efforts were defeated by the vectorial capacity of the mosquitoes, which were 100-1000 times higher than the critical value required to stop transmission of malaria. The conclusions of the study show that the failure to control malaria in similar environments was not the consequence of poverty or lack of institutional capacity: "The malaria control measures employed in the Garki Project failed to have a significant overall impact on malaria transmission, suggesting that these measures are unlikely to be of long-term use in the African dry savannah belt." This failure occurred despite the fact that "at all times during this study, it was known that the strategies employed were much too detailed and expensive for long-term use in the study area." (Loutan and others, n.d., p.15).

With no proven method of controlling malaria in sub-Saharan Africa and other areas of intense transmission, it is difficult to argue that poverty effectively causes malaria, or determines the success of control efforts.

A different sort of evidence that malaria is a cause of poverty comes from evolution. In areas with the most severe malaria today, sub-Saharan Africa and parts of the Middle East and India, many ethnic groups have developed a partial genetic defense against the ravages of malaria: sickle-cell trait. In some parts of Africa, this red blood cell abnormality is carried by 25-30% of the population (Weatherall, 1984). The value of sickle-cell's protection against malaria must be great because it comes at a very high cost: all children (in developing countries) who inherit the trait from both mother and father die before the age of childbearing. The burden of malaria on human wellbeing must have been high indeed for such a mutation to be beneficial. Milder congenital blood diseases, such as thalassemia in parts of southern Europe and Asia, confer some protection against malaria in regions where malaria is correspondingly less severe. These blood diseases highlight the importance of the burden of *falciparum* malaria relative to other forms since they only protect against *falciparum* infections (Luzzato, 1984).

The geographical specificity of malaria, the wide biological variation in the capacity of mosquito vectors, the inability to control malaria in Africa under experimental conditions, and the persistence of fatal blood diseases as a defense all point to a causation from malaria to poverty, not vice versa. Large-scale vector control projects require resources, but if they were clearly feasible, the resources would probably be forthcoming from the international community. Much of the effective malaria control (in subtropical areas) has in fact come from low-technology drainage and larvaciding,[6] which could be carried out independently by a poor tropical country if the technique offered a viable prospect of malaria control.

Anecdotes from countries that have eradicated malaria

A small number of the countries that had severe malaria earlier this century eradicated the disease. Many other changes were simultaneously occurring in the economies of these countries before and after eradication, but in almost all cases for which we have data, the countries experienced an acceleration of growth immediately following eradication, and faster growth than neighboring countries.

Malaria eradication in southern Europe has been a clear success story in the fight against malaria. Major control efforts in Greece, Italy, and Spain were started in the 1930s and completed in the late 1940s. Greece up to that time had been the most malarial country in Europe. Jones (1909) argues that the spread of *faliparum* malaria through most of Greece in the first millenium AD was the main factor in the decline of ancient Greek civilization. Greece was the site of major malaria epidemics in the nineteenth and early twentieth century, and the famed plain of Marathon became virtually uninhabited due to malaria despite very fertile soils. The use of DDT starting in 1946 had spectacular results (having a major influence on the subsequent WHO world eradication campaign), with malaria falling from 1-2 million cases per year in the early 1930s to only 5,000 in 1951 (Bruce-Chwatt and de Zulueta, 1980). Although complete eradication would take another twenty years, partly due to vector resistance to DDT, from an economic point of view malaria was under control.

The longstanding problem of malaria in Italy contributed to the major role of Italians in early malaria research. Before the control campaign, Italy had 300,000 cases of malaria per year with 20,000 deaths (Haworth, 1988). The Pontine Marshes south of Rome were rendered uninhabitable by the disease. *P. falciparum* was eliminated by the end of the 1940s, with *P. vivax* and *P. malariae* disappearing more slowly.

Spain reported 400,000 cases of malaria with 1700 deaths in 1943 (Haworth, 1988), but had effectively controlled the disease by the end of the 1940s.

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[6] See Kriton and Spielman (1989) on the major role of these simple technologies in many of the successful eradication efforts.

The period immediately before effective control of malaria was wartime and the post-war reconstruction. Due to the anomalies of the period and the lack of data, we compare growth in the post-control years of 1950-1955 to growth in the period 1913-1938 in Table 2.[7] In all three countries, economic growth in the post-control period was much higher than in the prewar period, and higher than growth in rest of Western Europe 1950-1955. In the prewar period, Greece and Italy also grew somewhat faster than Western Europe, but the increment in growth over the European average was also higher in the post-control period than the prewar period.

Portugal was another southern European country with severe malaria (over 100,000 cases per year in the 1940s – Haworth, 1988) that controlled malaria later than Greece, Italy and Spain. As shown in Table 3, growth accelerated after eradication in 1958 compared to the period before eradication, and once again the increment of growth over the average in the rest of Western Europe increased after eradication.

There are, unfortunately, few success stories for malaria eradication in developing countries, but the islands of Taiwan and Jamaica are among the few. Tables 4 and 5 show that growth accelerated in the two countries after eradication, in 1961 for Taiwan and 1958 in Jamaica. In both cases, growth also increased faster than growth in their respective regions.

A final example is U. S. South after World War II. 135,000 cases of malaria with 4000 deaths were reported in 1935 (Haworth, 1988). After large-scale drainage projects by the W.P.A. in the 1930s were followed by insecticide spraying after the war, malaria was brought under control by the end of the 1940s. In the decade of the 1950s, the South had its most dramatic catch-up with the rest of the country, going from 60% of the income per capita of the rest of the U.S. in 1950 to 68% in 1960 (calculated from Barro and Sala-i-Martin, 1991).

These country examples of growth after the control of malaria are merely suggestive. In every country examined economic growth was higher immediately after the eradication of malaria, but there were surely many other factors that influenced the economy at the same time. In several of the countries (Greece, Spain, and Jamaica), the rapid development of the tourism industry was only possible because of malaria eradication. No one thought of basking on shores of the Aegean when Greece was the most malarial country in Europe.

Malaria and economic growth

We have shown that most malarial countries are poor, and certain countries that managed to completely eradicate malaria in recent times have had more rapid economic growth than their neighbors. But can we find any general, statistically convincing evidence that initial malaria prevalence and reductions in malaria affect economic growth? Would a reduction in malaria significantly improve the economic prospects of poor countries?

The most direct way to assess the causal effect of malaria on country economic performance is to look at the relationship between economic growth, initial malaria levels and change in malaria

[7] GDP data for the 1913-1938 period are from Maddison, 1995. All other country GDP data in this section are from Summers and Heston, 1994.

over same period.   Above we saw that countries with severe malaria in 1965 have had much lower economic growth in the subsequent 25 years, but this did not take into account the initial poverty of countries, nor did it consider the role of human capital levels, government policies, or geographical variables. After the role of human capital, policy, and geography are taken into account, it is generally found that poorer countries grow faster than richer countries (Barro and Sala-i-Martin, 1995), so if malaria were really just a proxy for poverty, one would expect malarial countries also to grow faster.[8]

Table 6 presents a cross-country empirical growth estimation in the style of Barro (1991). Growth in GDP per capita over the 1965 to 1990 period is related to initial income levels, initial human capital stock, policy variables, and geographical variables. Human capital stock is measured by secondary education and life expectancy at birth. Policy is measured by trade openness over the period and an index of the quality of public institutions. The geographical variables include an indicator for the geographical tropics and the fraction of the population within 100 kilometers of the coast.[9] To these well-researched predictors of economic growth we add the malaria index in 1965 in regression 1.[10] Countries with severe malaria in 1965 had much lower economic growth, amounting to 1.3% lower growth per year, *even after other factors like initial income level, overall life expectancy and tropical location are taken into account*.

Reductions in malaria over the 1965-1990 period, in addition to malaria levels in 1965, are associated with much higher economic growth, as shown in regression 2. This corresponds to a 0.3% rise in annual economic growth for a 10% reduction in the malaria index. Over the twenty-five year period the average reduction in the malaria index was 7% among countries that had malaria in 1965. By extrapolation far outside the observed sample variation, a country with its whole territory affected by 100% *P. falciparum* malaria is predicted to raise permanently its annual growth by 3.2% if it completely eradicates malaria! Unfortunately, no country came near to accomplishing this. Of the fourteen countries in the sample with a malaria index above 0.9 in 1965, only one reduced it significantly: the malaria index in Zimbabwe fell by one-third.

Economic growth itself might be a cause of the observed malaria reductions if greater resources were available for malaria control, or a high institutional capacity were responsible both for economic growth and successful malaria control. In this case the estimates of the effect of malaria reduction on economic growth would be biased. To control for this possible endogeneity of malaria reduction, Regression 3 uses instrumental variables. The instruments are the shares of different ecozones in each country. Ecozones are good predictors of malaria reductions, since the reductions occurred mostly in certain nontropical ecozones, but ecozones are not themselves affected by economic growth. After correcting for the possible endogeneity of malaria reduction, the estimated effect on economic growth is slightly *larger*, so it is unlikely that

[8] In fact, over the 1965 to 1990 period, poor countries on average grew slower than rich countries, but poor countries also had lower initial human capital, followed less successful economic policies, and were disadvantaged geographically.

[9] Gallup and Sachs (1998) give a more detailed description of these variables.

[10] The malaria index for 1965 is constructed similarly to the malaria index for 1994 described in footnote 1. It is the product of the fraction of the population living in areas with high malaria risk in 1965 times the fraction of malaria cases in 1990 that are *P. falciparum.* This assumes that the *relative* share of *P. falciparum* cases did not change substantially from 1965 to 1990. The malaria data for 1965 were digitized from a WHO (1966) map.

malaria reduction (or resurgence) is a consequence of economic growth. A Hausman test finds no significant difference the ordinary least squares and instrumental variables estimates.

Regression 4 restricts the sample to non-sub-Saharan African countries. The size of the estimates for malaria are substantially the same. The change of malaria has a statistically significant coefficient, but the estimate for initial malaria loses statistical significance. Even without including the sub-Saharan African countries with the most severe malaria, a reduction in malaria corresponds to much higher economic growth. The results are almost unchanged if malaria reduction is instrumented with ecozones.

The growth regression results show that countries with severe malaria in 1965 had dramatically lower economic growth in the subsequent twenty-five years, after controlling for other factors that likely influenced growth, like initial poverty, economic policy, initial health and education levels, and tropical location. Countries that managed to reduce malaria over the period had much higher economic growth. These problems affected sub-Saharan Africa most severely because malaria levels are highest there, but the same relationship with economic growth holds in the non-African world.

Could malaria have such a large impact on economic growth?

We have presented several kinds of evidence suggesting that malaria has large economic effects. What are the channels through which malaria could be a major drag on the economy?

The traditional medical view of malaria at its most severe, in holoendemic areas, is that malaria contributes significantly to child mortality and can cause acute disease in pregnant women, but it does not have large effects on the fitness of other mature adults due to their partial immunity acquired through constant reinfection. McGregor (1988, p. 754) states this clearly: "in adult life...a host-parasite balance resembling commensualism is achieved. Despite sustained infectious challenge, adults constitute an economically viable work-force capable of coping with the strenuous physical activities that are required to maintain essential food supplies in subsistence agricultural communities." Though this view may be shared by many in the medical field, it has rarely been the subject of careful research. One wonders if the medical focus on mortality and acute disease obscures a general debilitation that could be caused by malaria. At least one article reports that long-term asymptomatic malaria may be the cause of chronic pains and lassitude among Europeans in East Africa (Wilks and others, 1965).

Formidable methodological and measurement problems confront any assessment of the impact of malaria on individuals and households in areas of stable malaria. There is not even a clear method for diagnosing which individuals suffer from malaria. Virtually the whole population carries malaria parasites, and the density of parasites is not a reliable measure of disease due to a variable immune response, which is still poorly understood. Fever symptoms are not specific to malaria. If everyone is infected with malaria, there is no comparison group for measuring the impact of malaria on diseased individuals relative to the healthy population.

If a clear measure of disease were available, one still faces the problem of assessing the cost of illness in extended rural households, accounting for the compensating behavior of other household members. It is hard to evaluate the cost of lost opportunities of household members who help out a person with malaria. Most attempts to directly measure the lost work due to malaria (which ignore these problems) find small or no impacts (Chima and Mills, 1998).

Malaria has life-long effects on cognitive development and education levels through the impact of chronic malaria-induced anemia and time lost or wasted in the classroom due to illness. The importance of these effects is speculative, though, since their impact is virtually unstudied. Iron-deficiency anemia *per se* has been shown to affect the cognitive skills of children as well as their cognitive abilities in later life (Pollit et al., 1989, and Lozoff et al., 1991).[11]

In short, the impact of malaria on the productivity of individuals in areas of stable malaria cannot be assessed with the current state of research. Whether or not individuals are significantly debilitated by malaria, there are several other channels through which malaria could have large impacts on the economy. The first is the impact of malaria on foreign direct investment and tourism. Malaria, unlike diseases resulting from poverty, does not discriminate between rich and poor victims. As long as malaria protection is imperfect and cumbersome, well-to-do foreign investors and tourists may stay away from malarial countries. A second channel through which malaria may affect the economy is limitation on internal movement.[12] The better educated and the ambitious who move to the largely malaria-free cities lose their natural protection due to lack of exposure. They may be reluctant to maintain contact with the countryside for fear of infection. Communities in unstable malaria areas may try to keep out people from stable malaria areas for fear of epidemics. In general, the transmission of ideas, techniques, and development of transportation systems may all be stunted by malaria.

Finally, the strong correlation of malaria with income levels and income growth may due to a range of tropical vector-borne diseases besides malaria. General health status should be picked up by life expectancy in the income growth regressions, but many tropical diseases, like yellow fever, trypanosomiasis, onchocerciasis, and leishmaniasis, have similar geographical ranges to malaria. Malaria is likely the most important of these diseases, but the measures of malaria used in this paper may be an indicator for a combination of tropical diseases. There may be important synergies between the diseases, so that areas affected by multiple tropical diseases are worse off than the sum of the impacts of the individual diseases. We are currently collecting data on the extent of other tropical diseases to investigate these effects.

Conclusion

The location and severity of malaria are mostly determined by climate and ecology, not poverty per se. Areas with severe malaria are almost all poor and continue to have low economic growth. The geographically favored regions that have been able to reduce malaria have grown

[11] It might be thought that malaria has a large impact in poor countries because of its interaction with malnutrition. Malaria, along with other childhood infectious diseases, has been found to exacerbate malnutrition. Surprisingly, though, malnutrition probably confers some protection to malaria. McGregor (1988, p. 763), in his survey, finds that "the balance of available evidence indicates that malnutrition in humans is more commonly antagonistic to malaria."

[12] We thank Andrew Spielman for suggesting this effect of malaria.

substantially faster afterwards. The estimated impact of malaria on the economy is very large, but the mechanisms behind the impact are not clear. Part of the apparent effect of malaria is probably due to other tropical diseases that are not independently measured.

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Table 1. Level of GDP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	lgdp95	lgdp50	lgdp90	lgdp95	lgdp95	lgdp95	lgdp95 (non-Africa)
Pop100km	1.30	0.45	0.53	0.60	0.66	0.26	0.36
	(6.56)	(2.17)	(2.89)	(2.78)	(3.41)	(1.70)	(2.33)
log Distance	-0.33	-0.19	-0.35	-0.31			
	(3.65)	(1.91)	(4.78)	(3.73)			
log Hydrocarbons per person	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	(2.19)	(2.73)	(2.15)	(1.90)	(2.46)	(1.80)	(2.05)
Tropical area (%)	-0.69	-0.13	-0.35	-0.33	-0.76	-0.19	-0.21
	(4.01)	(0.62)	(1.74)	(1.38)	(3.97)	(1.16)	(1.45)
Malaria index		-0.76	-1.07	-1.08	-0.88	-1.04	-1.08
		(4.63)	(5.94)	(5.02)	(3.68)	(5.40)	(2.77)
Socialist					-0.80	-0.12	-0.08
					(5.19)	(0.76)	(0.44)
Colony					-0.13	-0.05	-0.12
					(2.08)	(0.78)	(1.94)
Public institutions						0.22	0.22
						(6.57)	(7.17)
Trade openness						0.46	0.40
						(2.69)	(2.65)
Constant	10.40	8.68	10.92	10.75	8.72	7.17	7.15
	(13.94)	(11.14)	(18.70)	(16.89)	(46.39)	(27.92)	(29.97)
Observations	150	127	127	127	146	95	64
R^2	0.46	0.47	0.67	0.60	0.61	0.87	0.87

Robust t-statistics in parentheses

Table 2. GDP per capita growth before and after malaria eradication in southern European countries (late 1940s)

	GDP p.c. growth		Difference w/W. Europe	
	1913-38	1950-55	1913-38	1950-55
Greece	2.1	3.6	1.1	1.3
Italy	1.0	5.3	0.1	3.0
Spain	-0.4	6.2	-1.4	4.0
Western Europe	0.9	2.3	0.0	0.0

Table 3. GDP per capita growth before and after malaria eradication in Portugal (1958)

	1953-58	1958-63	Change
Portugal	3.0	5.3	+2.3
Western Europe	1.9	3.8	+1.9
Difference	+1.1	+1.5	+0.4

Table 4. GDP per capita growth before and after malaria eradication in Taiwan (1961)

	1956-61	1961-66	Change
Taiwan	2.8	5.8	+3.0
East Asia	3.4	5.5	+2.1
Difference	-0.6	+0.3	+0.9

Table 5. GDP per capita growth before and after malaria eradication in Jamaica (1961)

	1956-61	1961-66	Change
Jamaica	3.4	4.1	+0.7
Central America and Caribbean	2.6	3.1	+0.5
Difference	+0.8	+1.0	+0.2

Table 6. Growth of GDP

	(1)	(2)	(3)	(4)
	gr6590	gr6590	gr6590 (IV)	gr6590 (non-Africa)
log GDP 1965	-2.4	-2.4	-2.4	-2.3
	(7.70)	(7.38)	(7.20)	(5.92)
log secondary school years	0.1	0.1	0.0	0.0
	(0.80)	(0.44)	(0.29)	(0.02)
log life expectancy	3.7	3.0	2.7	3.9
	(3.83)	(3.38)	(2.58)	(2.40)
openness	1.7	1.5	1.5	1.6
	(4.46)	(4.36)	(4.20)	(3.79)
public	0.3	0.3	0.4	0.3
	(3.08)	(3.54)	(3.58)	(2.52)
tropics	-0.9	-1.0	-1.0	-1.0
	(2.38)	(2.72)	(2.65)	(2.75)
pop100km	0.7	0.7	0.7	0.6
	(2.40)	(2.61)	(2.57)	(1.59)
Malaria index	-1.3	-1.8	-2.0	-1.2
	(2.41)	(3.63)	(4.06)	(1.23)
d Malaria index		-3.2	-4.4	-2.7
		(3.52)	(2.42)	(2.04)
Constant	3.1	6.0	7.1	2.1
	(0.82)	(1.66)	(1.74)	(0.35)
Observations	73	73	73	58
R^2	0.77	0.80	0.80	0.77

Robust *t*-statistics in parentheses

Figure 1.
Malaria risk - 1946, 1965, 1994

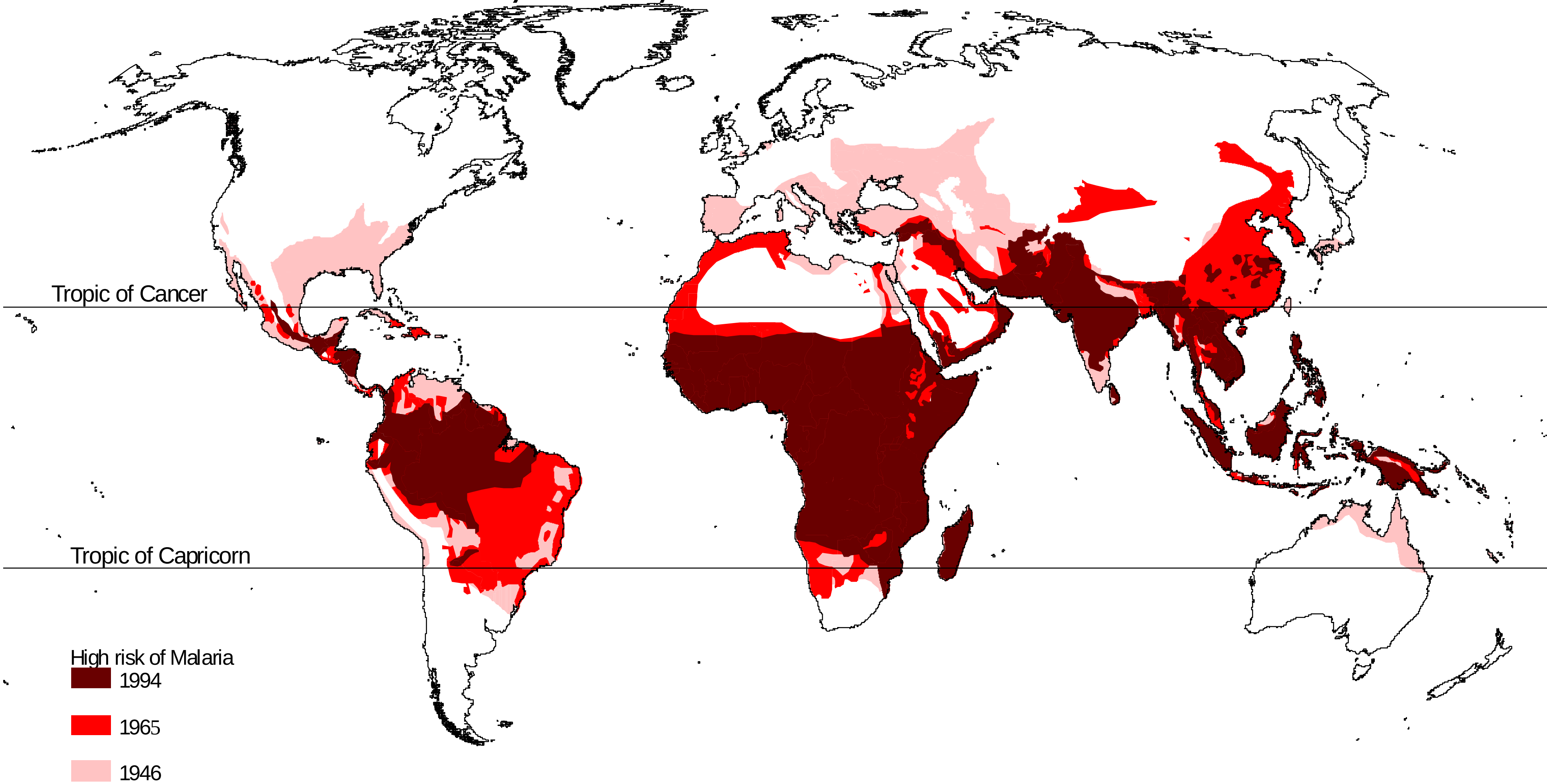

Figure 2.
GDP per capita 1995

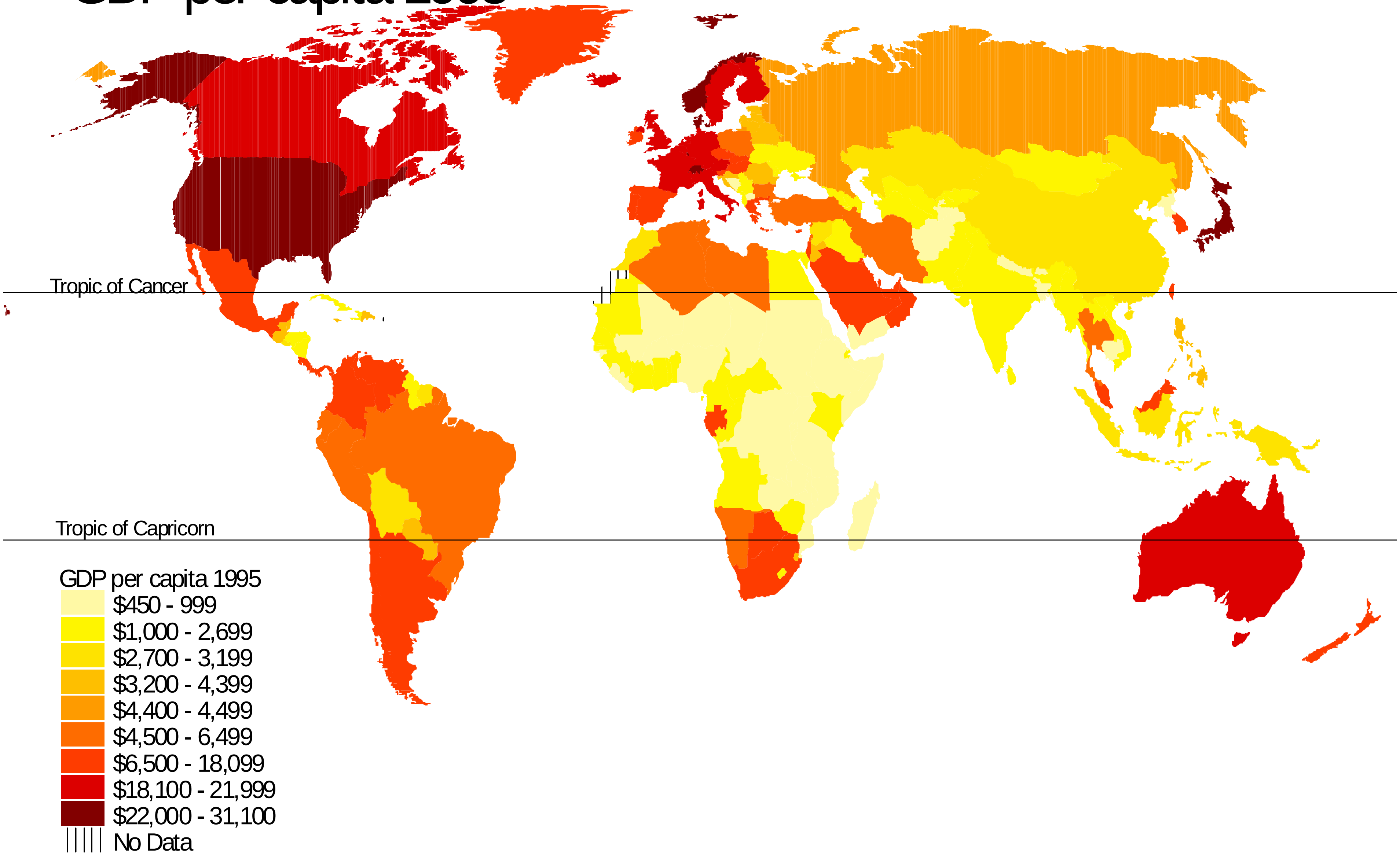

Figure 3.

Malaria Index 1965

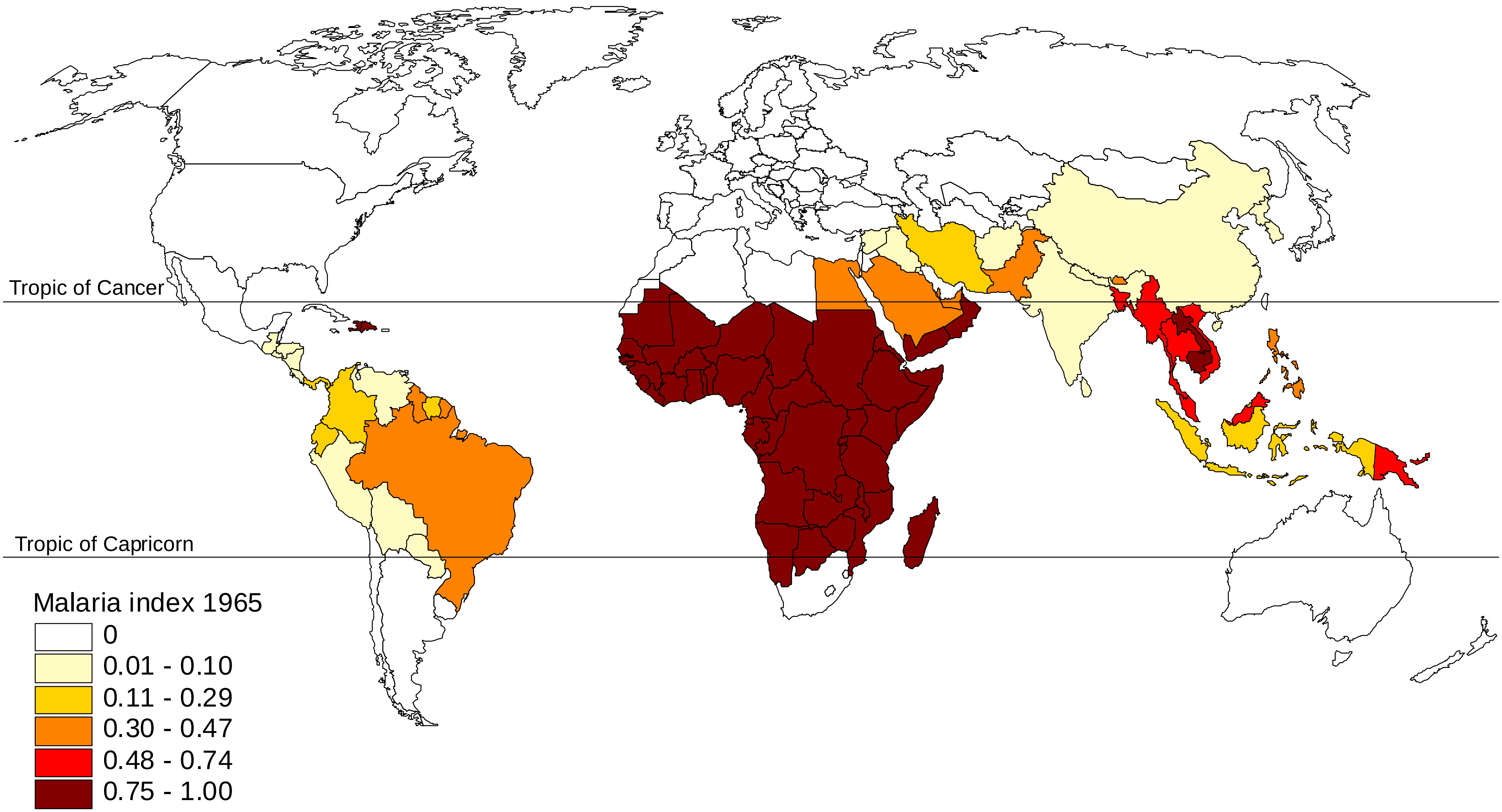

Figure 4.

Malaria Index 1994