Malaria:
Disease Impacts and Long-Run Income Differences

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Motivation

- How important are disease burdens in explaining long-run growth and income differences?

- Fogel: health and nutrition improvements were an important source of economic growth in the West.

- Sachs: differences in disease burdens across countries can account for big disparities in income levels and growth rates.

- Sachs: tropical countries face systematically harsher disease burdens.

- Sachs: malaria is perhaps the single greatest development challenge facing poor countries, especially in Africa.

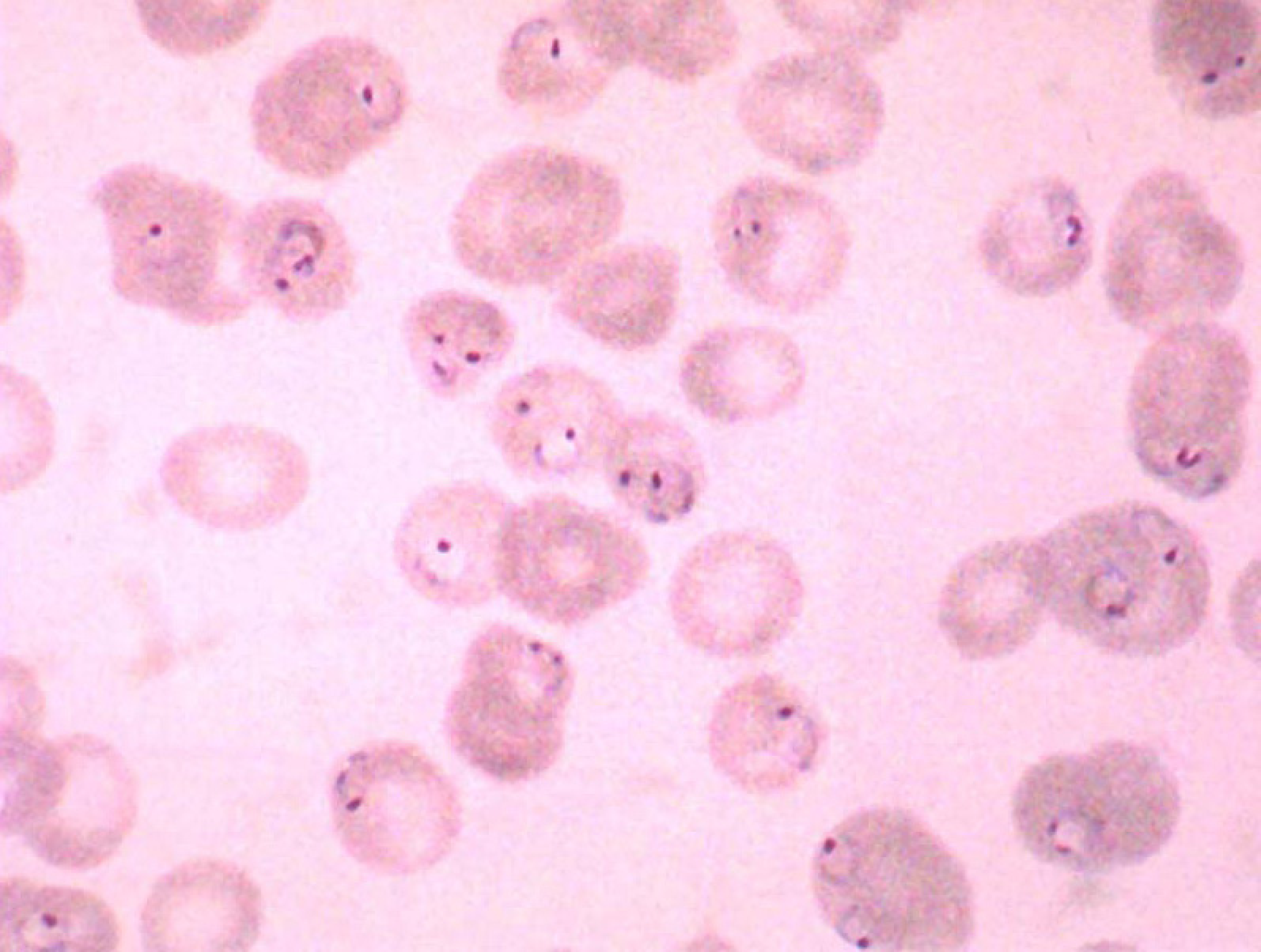
Malaria

- **A parasitic disease causing over 300 million episodes of "acute illness" annually and perhaps one million deaths.**

- **Most of the deaths are of children, and most are in Africa.**

- **Caused by any of four species of *Plasmodium* parasites, which are transmitted by various species of *Anopheles* mosquitoes.**

- **40 percent of the world's population lives in countries where malaria is endemic.**



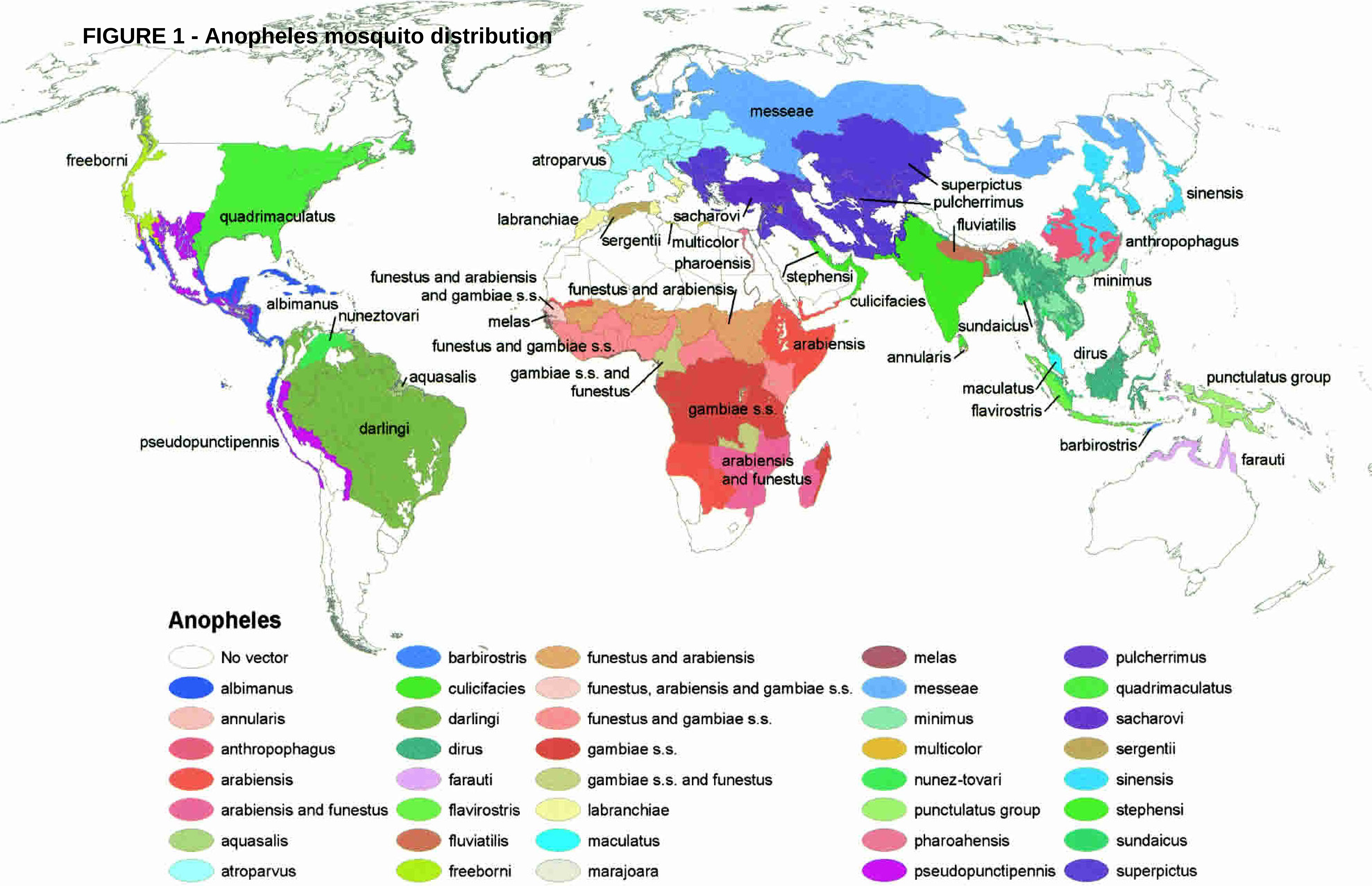
Malaria, cont.

- **The disease is ancient and was formerly endemic in many parts of Europe and North America (possibly brought by Europeans).**

- **The intensity of the disease (extent of infection) and the severity of the disease (for individuals) vary widely across locations.**

- **Local ecological conditions play an important role in accounting for the intensity and severity of the disease, largely because they influence the species of mosquito that is present.**

FIGURE 1 - Anopheles mosquito distribution



Economic Impacts

- **Direct costs of the disease include:**
  - **Lives lost**
  - **Time lost**
  - **Productivity lost (including through reductions in cognitive functioning)**
  - **Expenditures on medicine and prevention**
  - **Expenditures (public and private) on research, treatment, mosquito control, etc.**

- **Indirect costs include both personal and social costs:**
  - **Consequences for fertility, demography**
  - **Effects on human capital investments**
  - **Effects on trade and investment**
  - **Effects on managerial ability and technology adoption**

Estimates of economic impact

- **Many micro studies of disease impacts on individual and community health and income.**

- **Less available at the macro level.**

- **Problems in aggregating micro studies into macro effects!**

  - **Micro studies ignore general equilibrium impacts (e.g., on wages)**
  - **Also tend to ignore dynamic impacts such as impacts on fertility, investment, etc.**

Could Malaria Cause Poverty?

- **Gallup and Sachs (2000) note that the 44 countries with intensive disease burdens had per capita income of $1,526 in 1995, compared with $8,268 for the 106 countries without intensive malaria burden.**

- **In a cross-country regression analysis, GS argue that countries with intensive malaria burdens grew slower, by 1.3 percentage points annually.**

- **Similar findings by McCarthy, Wolf, and Wu (1999), Sachs and Malaney (2002), and others.**

Figure 1.

Malaria risk - 1946, 1965, 1994

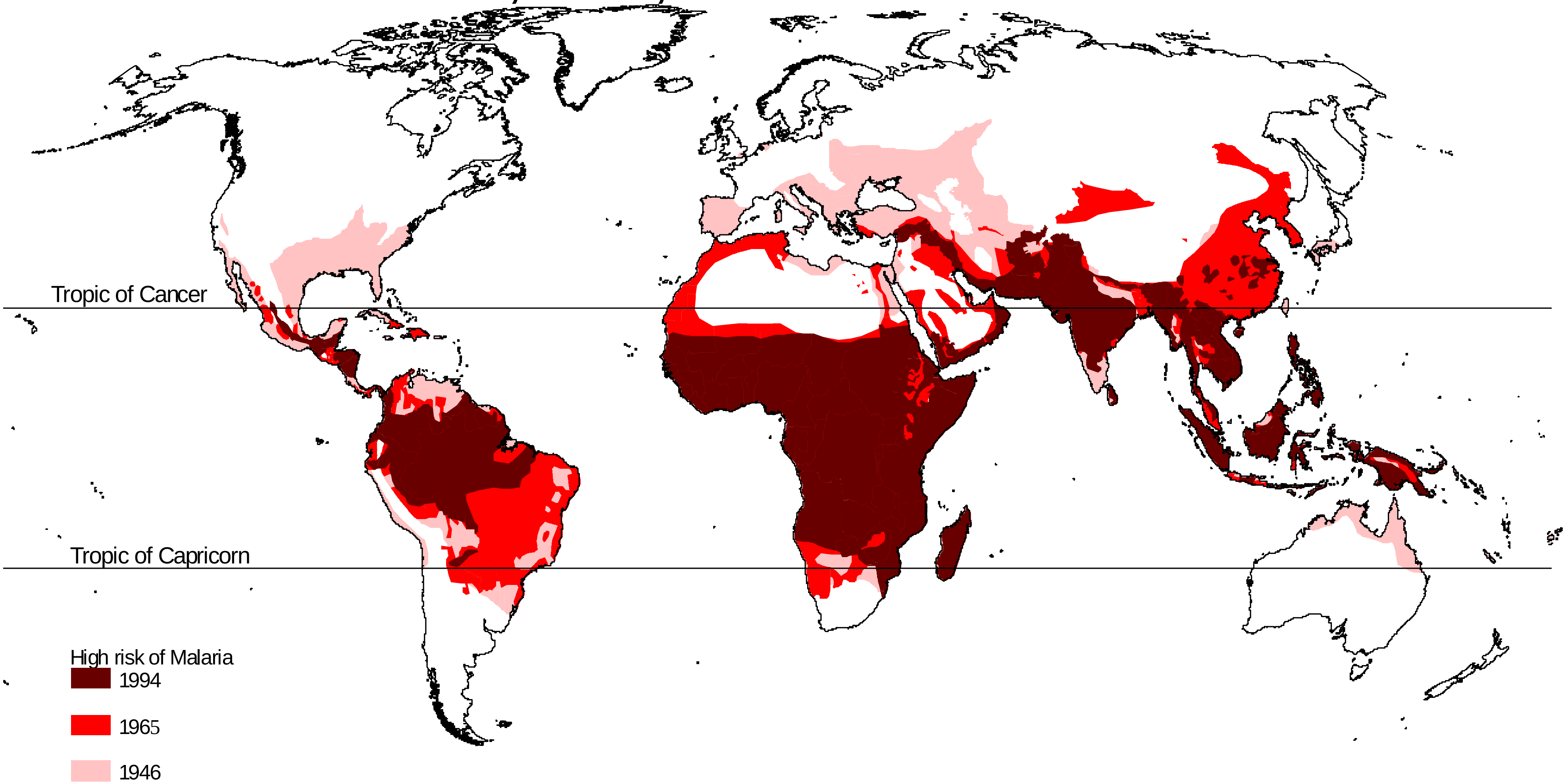
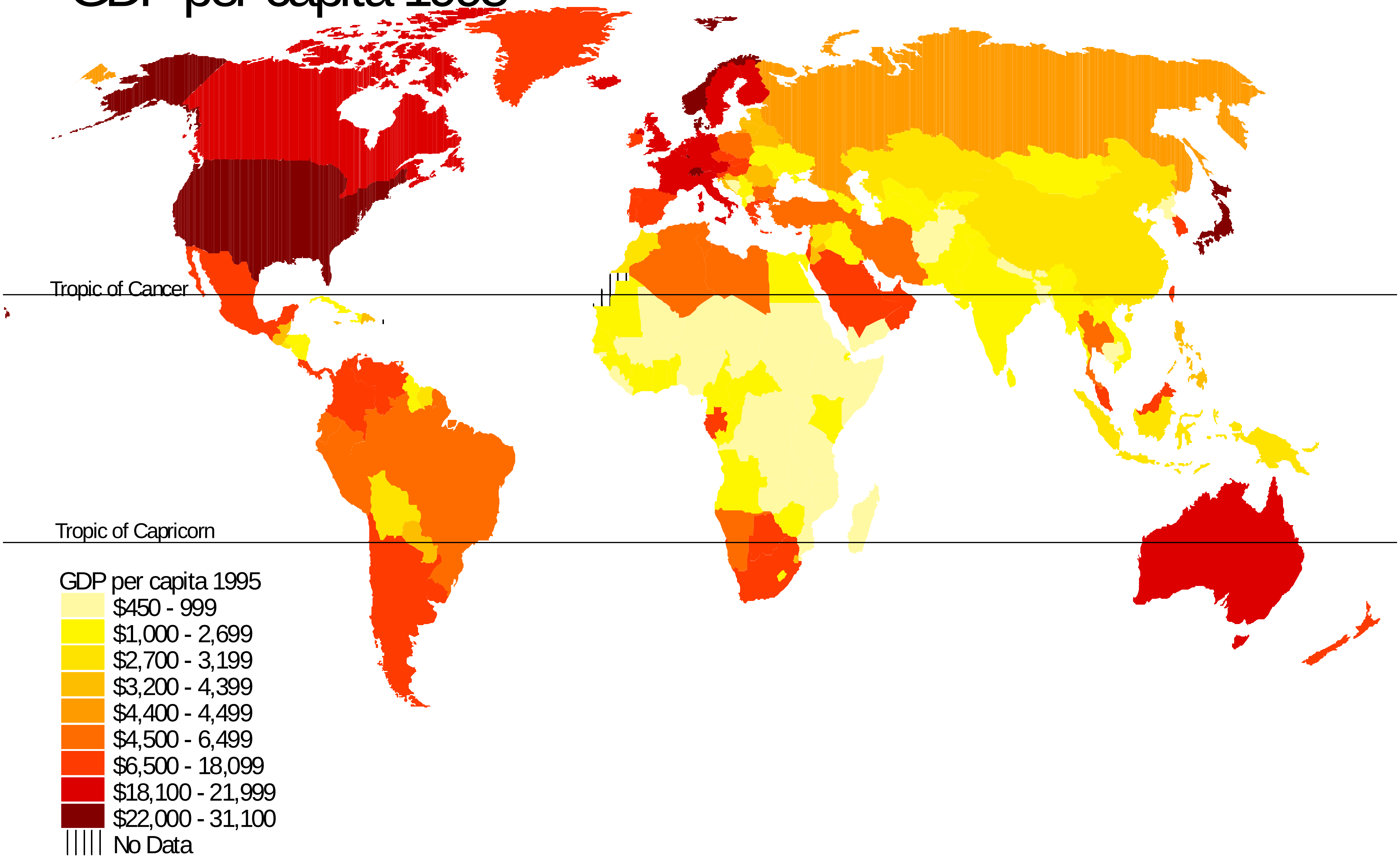


Figure 2.
GDP per capita 1995



Malaria and Poverty, cont.

- **Sachs argues that this effect is an ecologically based one; some regressions include "malaria ecology" rather than malaria intensity, and regressions are significant even when other geographic controls are included.**

- **Sachs argues in consequence that global funding for malaria control and prevention should be increased from \$100-\$200 million annually to \$2-\$3 billion annually.**

- **This would be a big change in current patterns of foreign assistance!**

Figure 3.

Malaria Index 1965

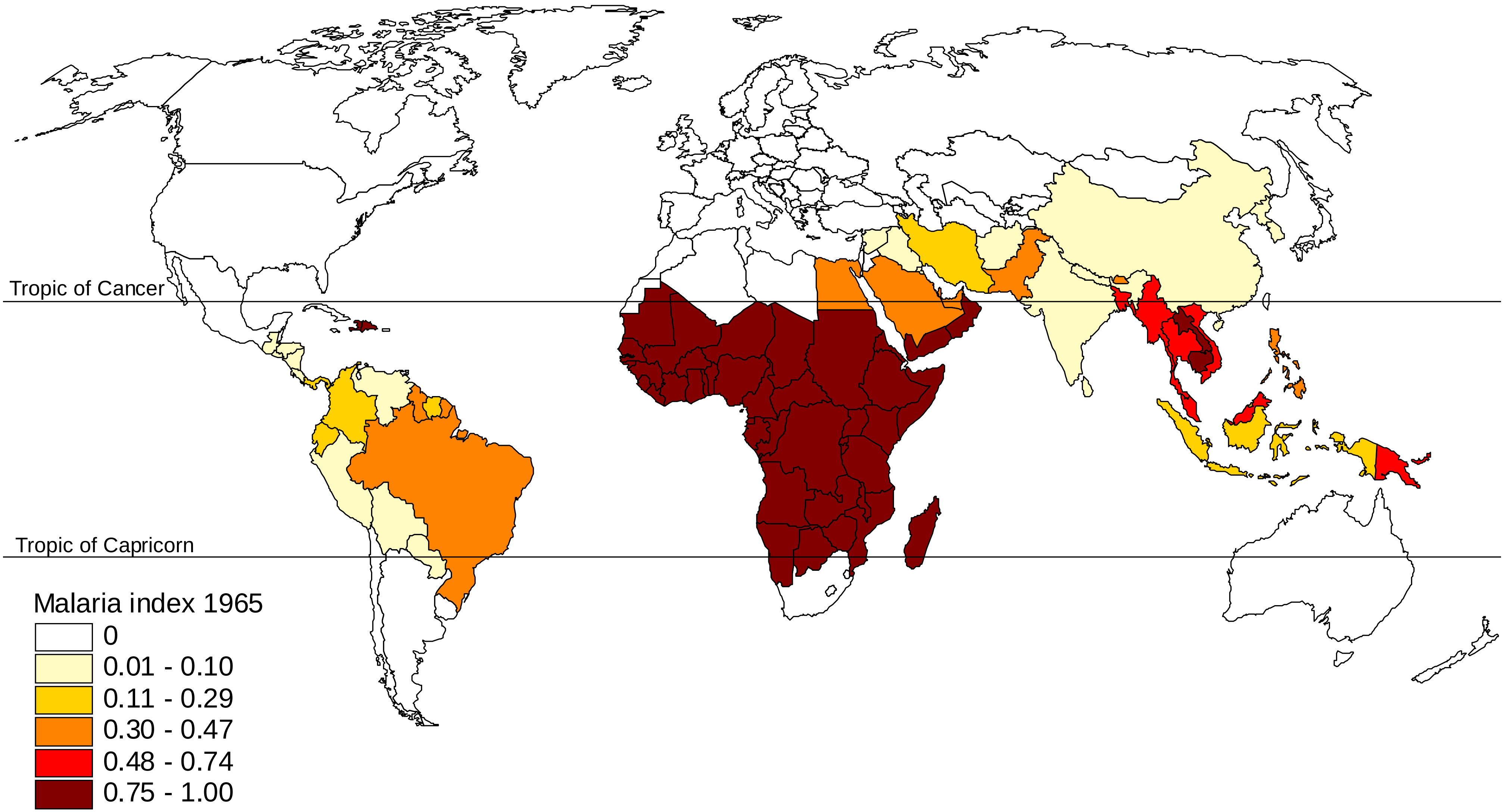


Figure 4.

Malaria Index 1994

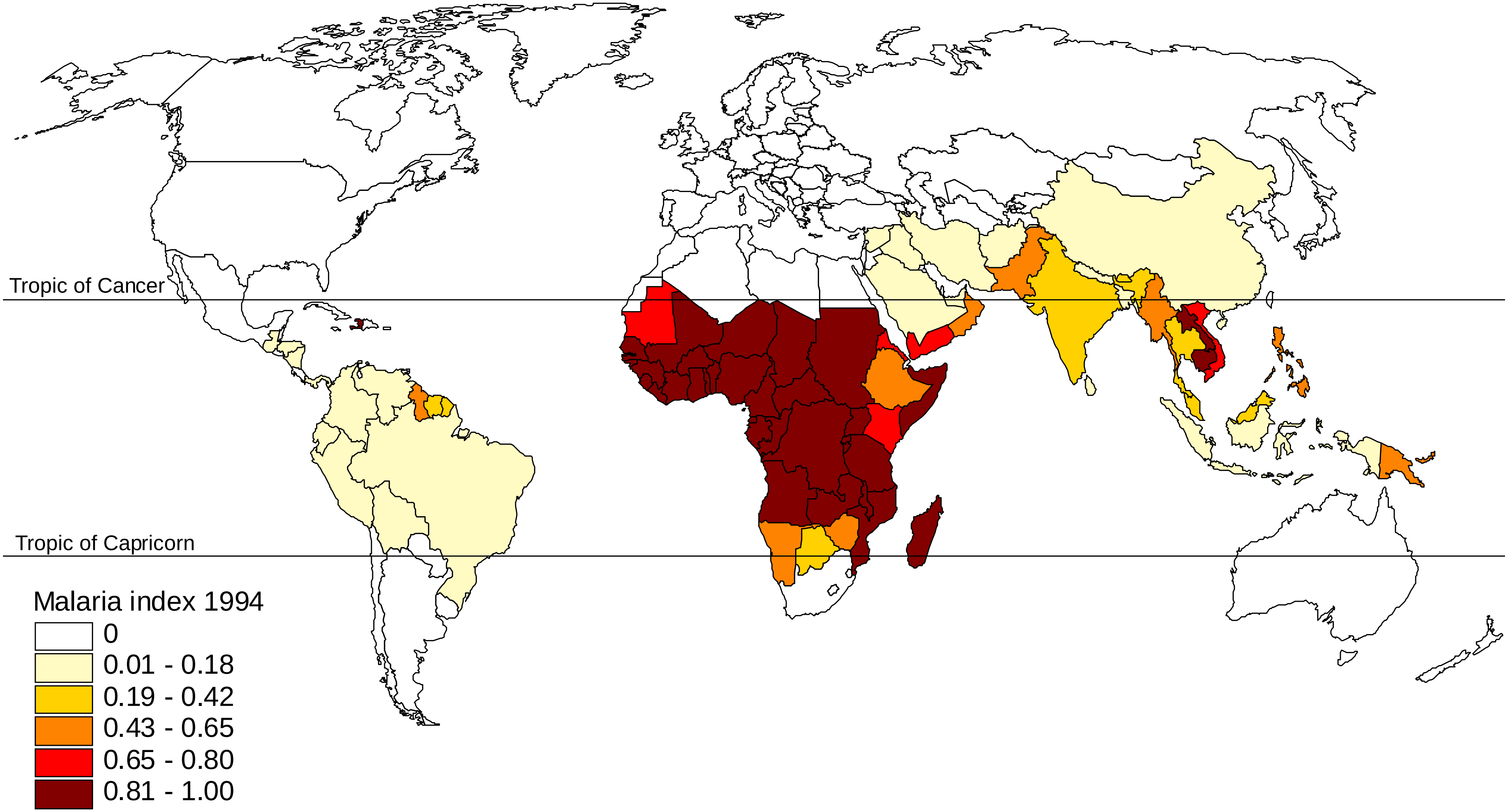
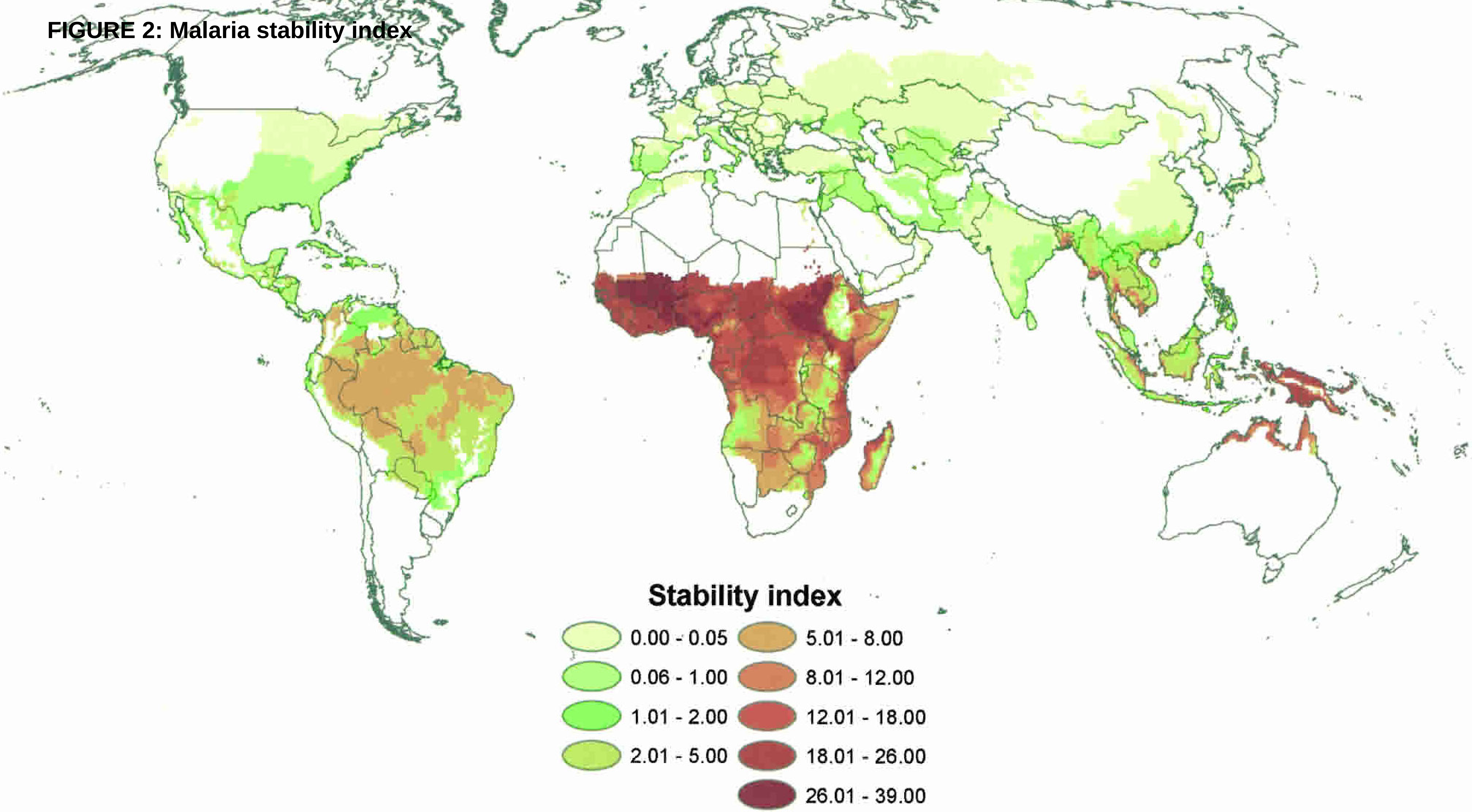


FIGURE 2: Malaria stability index



Some Doubts

- **Should we take this argument seriously? Reasons to be skeptical.**

  - **Obvious problems with reverse causation…Does malaria cause poverty, or does poverty cause malaria?**

  - **If malaria is such a problem for growth, why has the disease effectively been eradicated from North America and Europe? Clearly growth has had an impact.**

  - **Disease impacts on growth and levels of income are not clear; direct effects on demographic structure, mortality, and morbidity tend to have minor importance in a growth framework (especially for a disease that largely kills children under 5).**

Plausibility

- **There are also reasons to take the argument seriously that malaria has an impact on growth and income.**

  - **A few studies show long-run impacts on human capital, fertility, and individual income (Bleakley 2003, 2005; A. Lucas 2005).**

  - **Malaria ecologies really do differ substantially across countries based only on climate, geography, and the species of mosquitoes present.**

  - **Perhaps this exogenous dimension really does account for important differences across countries today.**

- **McNeill (1976):**

  [T]he mosquito species which is Europe’s most efficient vector of malaria… prefers to feed on cattle. If enough alternate sources of blood are available to them, these mosquitoes will eschew potential human hosts and thus interrupt the chain of infection, since cattle do not suffer from malaria

Modeling malaria

- **Need a model in which both directions of causality are present (malaria reduces income/productivity; income/productivity can reduce malaria)**

- **Need a model in which it is possible to consider behavioral responses to disease burden and also dynamic impacts of disease.**

- **Want a model in which it is possible to consider potential impacts of malaria control policy.**

Model Environment

- **Many individuals, born identical.**
- **New individuals are born each period (quasi-endogenously).**
- **Some individuals die each period (quasi-endogenously).**
- **Individuals are exposed to disease each period; some fall sick.**
- **Sick individuals face heightened probabilities of death and lower labor productivity.**

Model Environment, cont.

- **Individuals are born naked but may accumulate assets.**
- **No credit or insurance markets.**
- **Individuals may, at any point during their lives, make a lumpy purchase of a preventive good that will confer future immunity from disease.**
- **Assets vanish when people die.**

Preferences

- **Period utility is given by:** $$u\left(c_t; s_t\right) = \frac{\left(c_t - \overline{c}\right)^{1-\rho}}{1-\rho} s_t$$ $$s_t \in \left\{\overline{s}, 1\right\},\ 0 \leq \overline{s} \leq 1$$

- **Lifetime utility is given by:** $$\sum_{t=0}^{\infty} \beta^t u\left(c_t; s_t\right)$$

Endowments

- **One unit of labor time each period.**
- **All individuals are born healthy.**

Health and Labor Productivity

- **Individuals face health shocks to labor productivity:**

$$h_t = \begin{cases} \overline{h}, \text{ if } s_t = \overline{s} \\ 1, \text{ if } s_t = 1 \end{cases}$$

- **They also face idiosyncratic non-health shocks:**
  - **Parameter** π_t evolves according to a Markov process

Prophylaxis

- **Individuals may choose in each period after birth whether or not to buy protection from the disease.**

- q is the quantity of goods

- $p_t \in \{0,1\}$ **is the decision to purchase protection.**

Technology

- **Aggregate Cobb-Douglas production:**

$$Y_t = K_t^{\alpha} L_t^{1-\alpha}$$

$$K_t = \sum_i k_{it}$$

$$L_t = \sum_i l_{it}$$

Individual's problem

- **Choose functions** $\{c_t, k_t, p_t\}$ **to maximize lifetime utility subject to a period budget constraint given by:**

$$c_t + k_{t+1} + p_t q \le w_t h_t \pi_t + r_t k_t,$$

- **Note that the disease protection decision provides lifetime immunity; it need not be renewed.**

Demographics and Disease Status: Notation

- N_0 **Initial population size**
- f_s **fertility rate for sick**
- f_h **fertility rate for healthy**
- d_s **death rate for sick**
- d_h **death rate for healthy**
- I **infection rate (in some versions, endogenously determined)**

- $\boldsymbol{N}$ **Population size**
- $\boldsymbol{S}$ **Fraction sick**
- $\boldsymbol{H}$ **Fraction healthy**
- $\boldsymbol{V}$ **Fraction protected from disease**
- $\boldsymbol{P}$ **Fraction purchasing protection at a particular date**

The Sick and the Healthy

$$S = \frac{\sum_i S_i}{N}, \text{ where } S_i = \begin{cases} 1, \text{if } s_i = \overline{s} \\ 0, \text{otherwise} \end{cases}$$

$$H = 1 - S$$

The Protected and Unprotected

$$P = \frac{\sum_i p_i}{N} \text{ (fraction of population purchasing protection)}$$

$$P_h = \frac{\sum_{i \in H} p_i}{H} \text{ (fraction of healthy purchasing protection)}$$

$$P_s = \frac{\sum_{i \in S} p_i}{S} \text{ (fraction of sick purchasing protection)}$$

Laws of Motion

$$N' = N - d_s S - d_h H + f_s S + f_h H$$

$$S' = \frac{N\left[S - d_s S + IH(1-V)(1-d_h)\right]}{N - d_s S - d_h H + f_s S + f_h H}$$

$$V' = \frac{N\left[V - d_s V_s - d_h V_h + P_h H\left(1-d_h\right) + P_s S\left(1-d_s\right)\right]}{N - d_s S - d_h H + f_s S + f_h H}$$

$$K' = K + Y - C - PqN$$

Infection Rates

- **Several different approaches used:**

- **Constant infection rate: *I* = 0.25**

- **Minimum infection rate with externalities:** $I = \min\{\Omega + S, 1\}$

- **Fully endogenous infection rate:** $I' = ZI^{\mu}$**, where Z is an index of the malaria ecology.**

Equilibrium

- **Use recursive approach.**

- **Population: several approaches. One is to set fertility rates so that equilibrium is characterized by stable population levels.**

- **Multiple steady states are expected as a function of the disease dynamics:**
  - **Every economy has a steady state in which no one is infected.**

  - **Without making an existence claim, there is also likely to be at least one interior steady state.**

  - **Both of these equilibria are of interest.**

Quantitative exercises

Experiment 1:

- **Consider a model economy in which protection is not possible, and ask what happens as it moves from the malarial steady state to the healthy steady state.**
- **Are there substantial impacts on income, as Sachs suggests?**

Experiment 2:

- **Repeat the previous experiment with costly prophylaxis.**

Experiment 3:

- **Consider a set of model economies in which exogenous disease ecology differs.**
- **See how these differences affect steady-state income.**

Parameter values

Fertility and Demographic Parameters

- f_s **0.000**
- f_h **taken to be endogenous, to achieve stable population**
- d_s **0.075**
- d_h **0.015**

Preference Parameters

- $\overline{s}$ **0.9**
- $\overline{c}$ **0.0**
- β **0.95**
- ρ **1**

Production and Productivity Parameters

- $\bar{h}$ **0.9**
- α **0.36**
- **Idiosyncratic shock size: 0.224**
- **Transition matrix for shocks:**

$$\begin{bmatrix} .9 & .1 \\ .1 & .9 \end{bmatrix}$$

Experiment 1: Prevention is effectively non-existent

- **Set $q = 1000$ so that prevention is unaffordable.**
- **Solve for the steady-state in which people are healthy.**
- **Solve for the steady-state in which people are sick.**
- **Compare income levels and other economic variables across these two steady states.**

Experiment 1 Results. (Multiple steady states with different costs of protection.)

$q = 1000$ $z = 0.7$	Low	High
Endogenously determined fertility rate	**0.069**	**0.0150**
Proportion sick	**0.901**	**0.0000**
Proportion protected from disease	**0.0000**	**0.0000**
Average assets	**2.9574**	**12.0797**
Average output	**1.3909**	**2.4521**
Average consumption	**1.1551**	**2.2668**

Discussion of Experiment 1

- **If no prevention method is available, the disease is widespread and has a large effect on output, consumption, and birth/death rates.**

- **Output per person is 43% lower in the malarial economy than it would be if the disease were eradicated.**

- **Consumption per capita is 49% lower.**

- **Assets are much lower!**

Experiment 2

- **Reduce the cost of protection to a reasonable level (e.g., set q = 0.6, corresponding to about 20-25 percent of annual income).**

- **Solve for the two steady states. One is the same as the benchmark; the other is the "sick and poor" steady state.**

Experiment 2 Results. (Multiple steady states with different costs of protection.)

q = 0.6 **z = 0.7**	**Low**	**High**
Endogenously determined fertility rate	**0.0150**	**0.0150**
Proportion sick	**0.0004**	**0.0000**
Proportion protected from disease	**0.9772**	**0.0000**
Average assets	**11.994**	**12.0797**
Average output	**2.4458**	**2.4521**
Average consumption	**2.2533**	**2.2668**

Discussion of Experiment 2

- **Even a relatively costly prophylaxis opportunity is used extensively.**

- **People are willing to forego other consumption to buy prophylaxis.**

- **Prevention costs must be very high to prevent people from taking advantage of them…**

- **Implications for a wide range of possible preventive measures that have transaction costs: moving location, changing sector of employment, etc. These costs must be very large, or else efficacy is not very high!**

Figure 1: Prevention costs and steady-state output levels

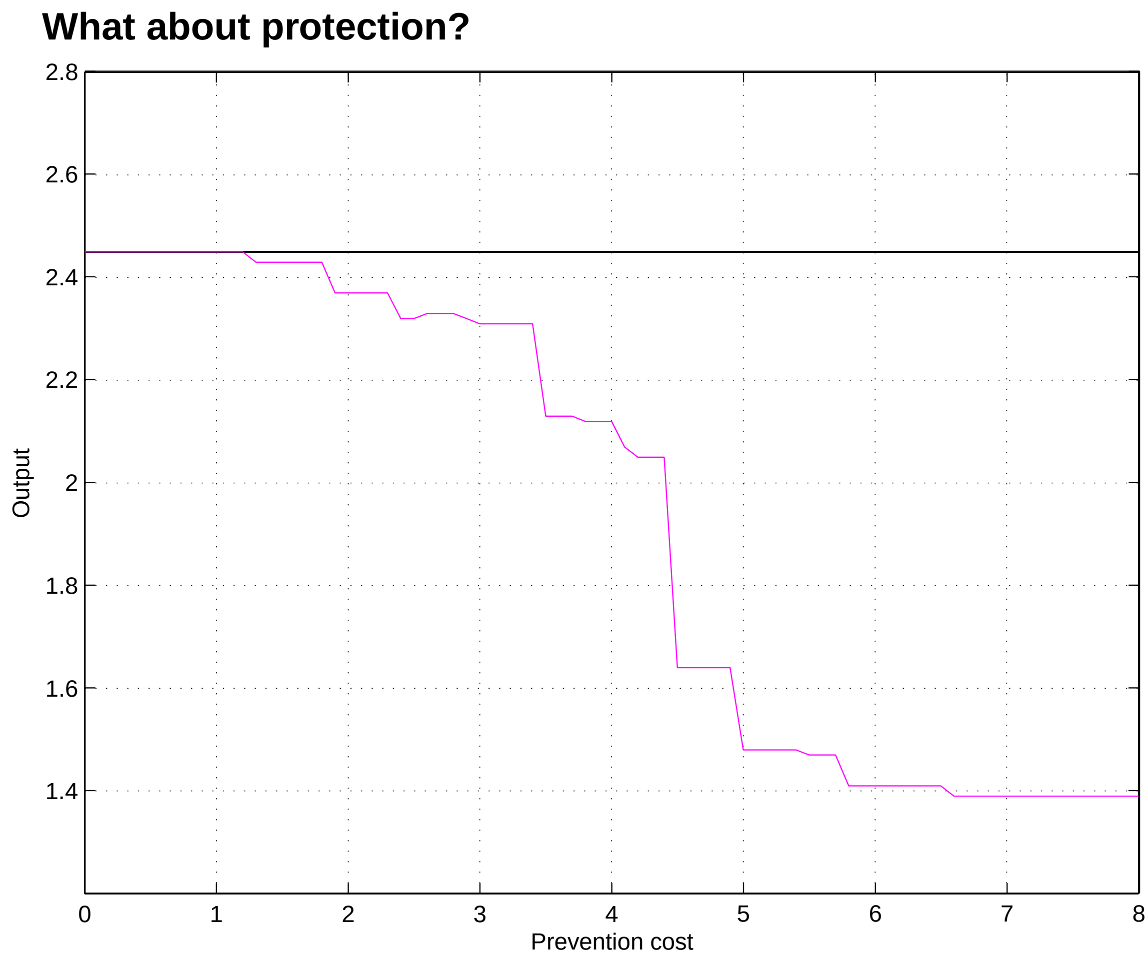


Figure 2: Proportions sick and protected in relation to prevention cost.

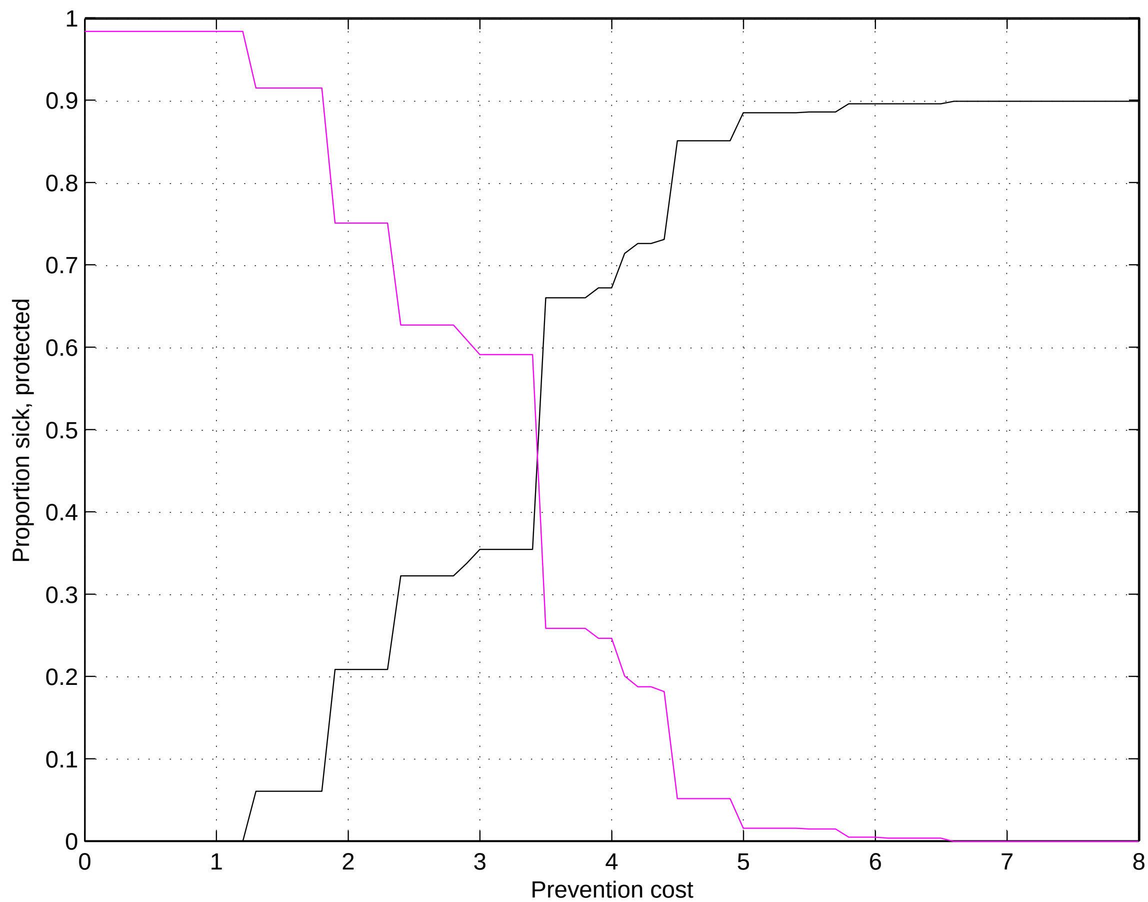


Figure 3: Robustness to changes in minimum consumption level.

Robustness

$\bar{c} = 0.5$:

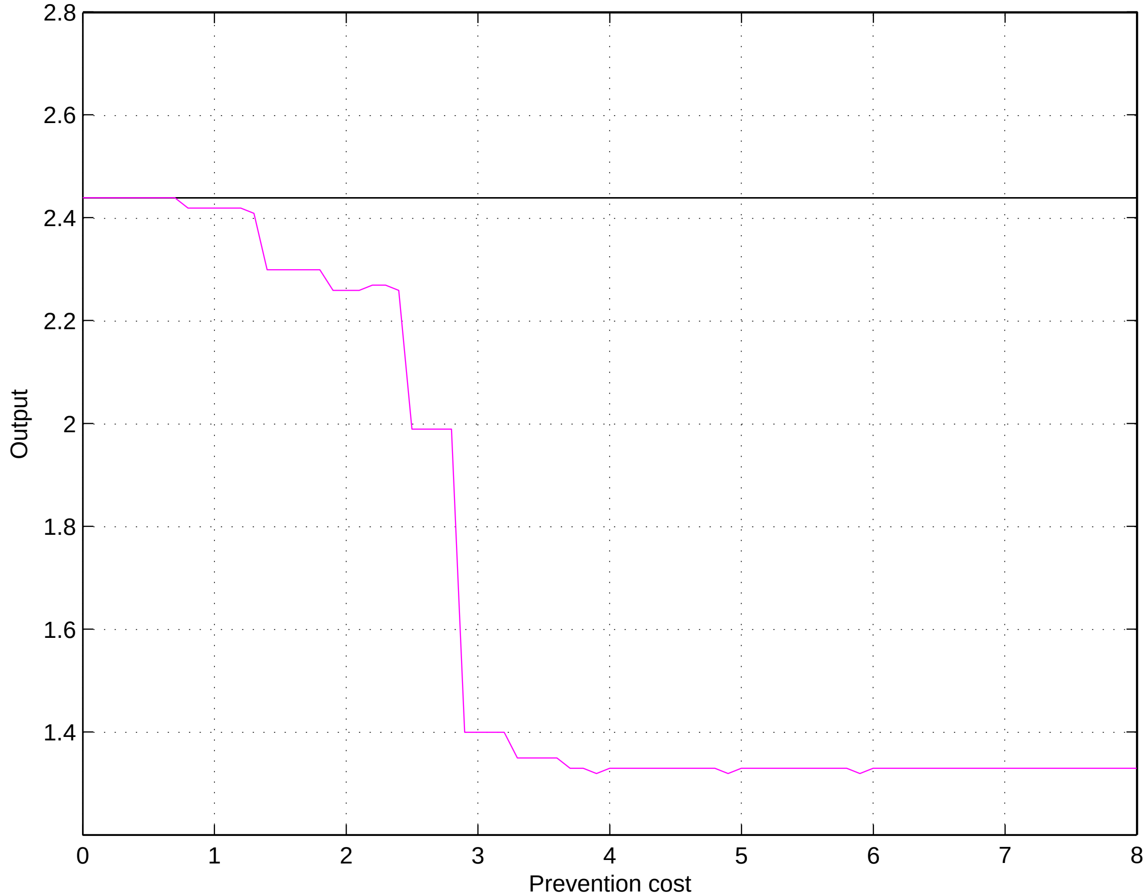
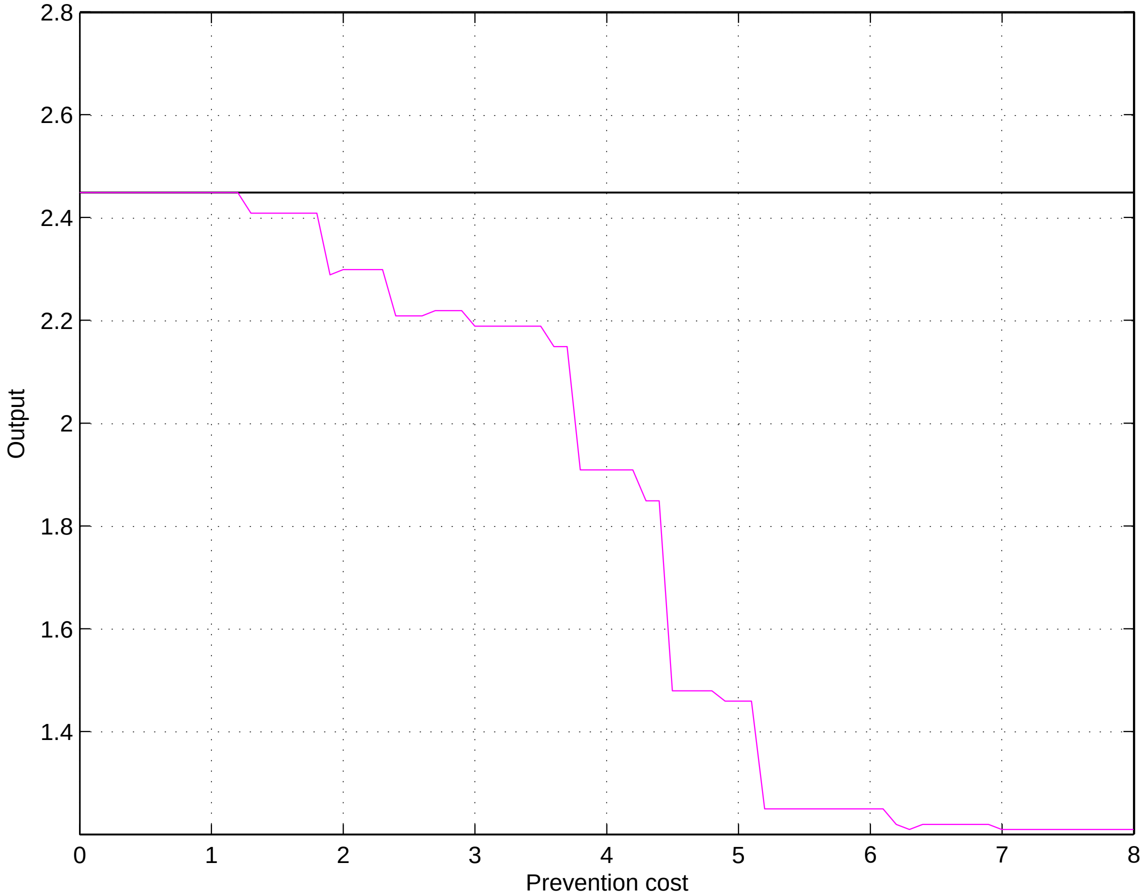


Figure 4: Robustness to changes in effective labbor units of the sick.

$\bar{h} = 0.75$:



Implications

- **People will buy protection if it is available at any reasonable cost. In our model, the cost has to reach approximately one year's annual income before people will decline to buy it.**

- **Those who do not buy the preventive goods instead treat malaria as an additional form of income risk and self-insure by holding higher levels of assets.**

- **Although the impact on individual productivity is large (10%), the steady-state impact on income may be small.**

- **Utility comparisons are hard; many more people are born and die in the poor economy, What utility weight to assign to births and deaths?**

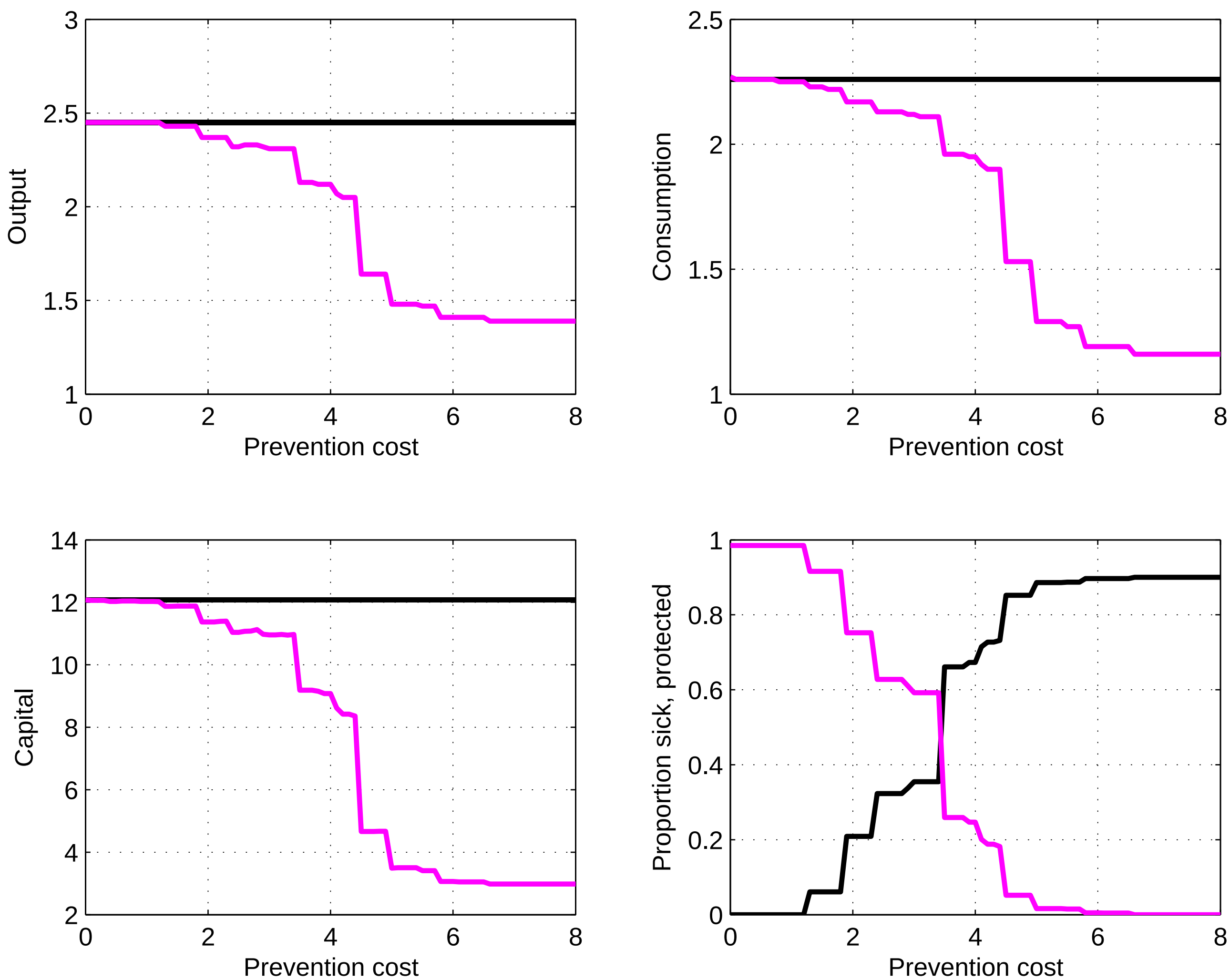
Conclusions and Directions for Further Research

- **Suggests that behavioral responses and substitution mechanisms may mute the impacts of malaria.**

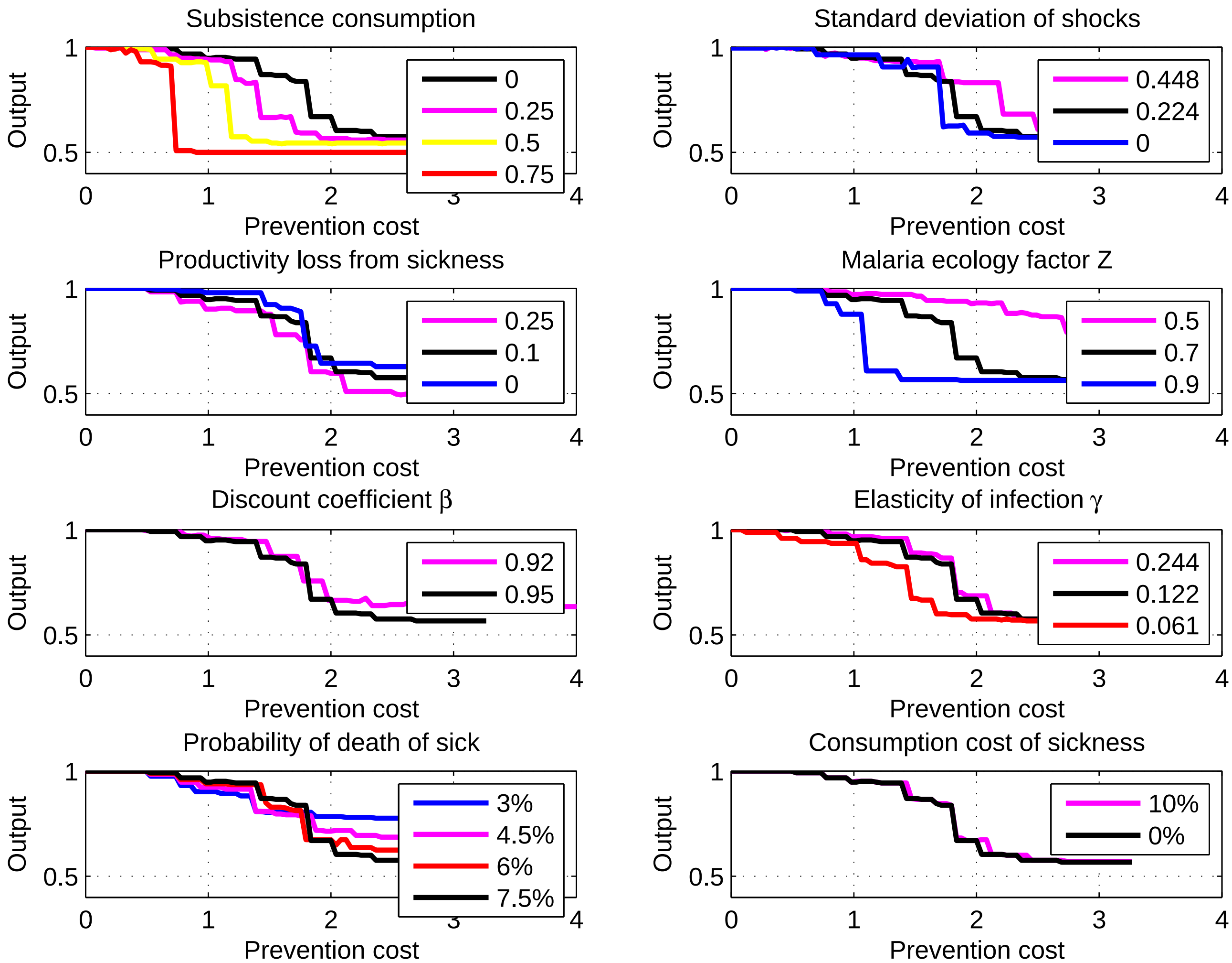
- **Even if a disease is widespread and has a significant impact on individual productivity, it may not matter much for aggregate income levels or growth rates.**

- **Need to incorporate a greater level of realism regarding disease dynamics and effects on productivity, fertility, etc.**

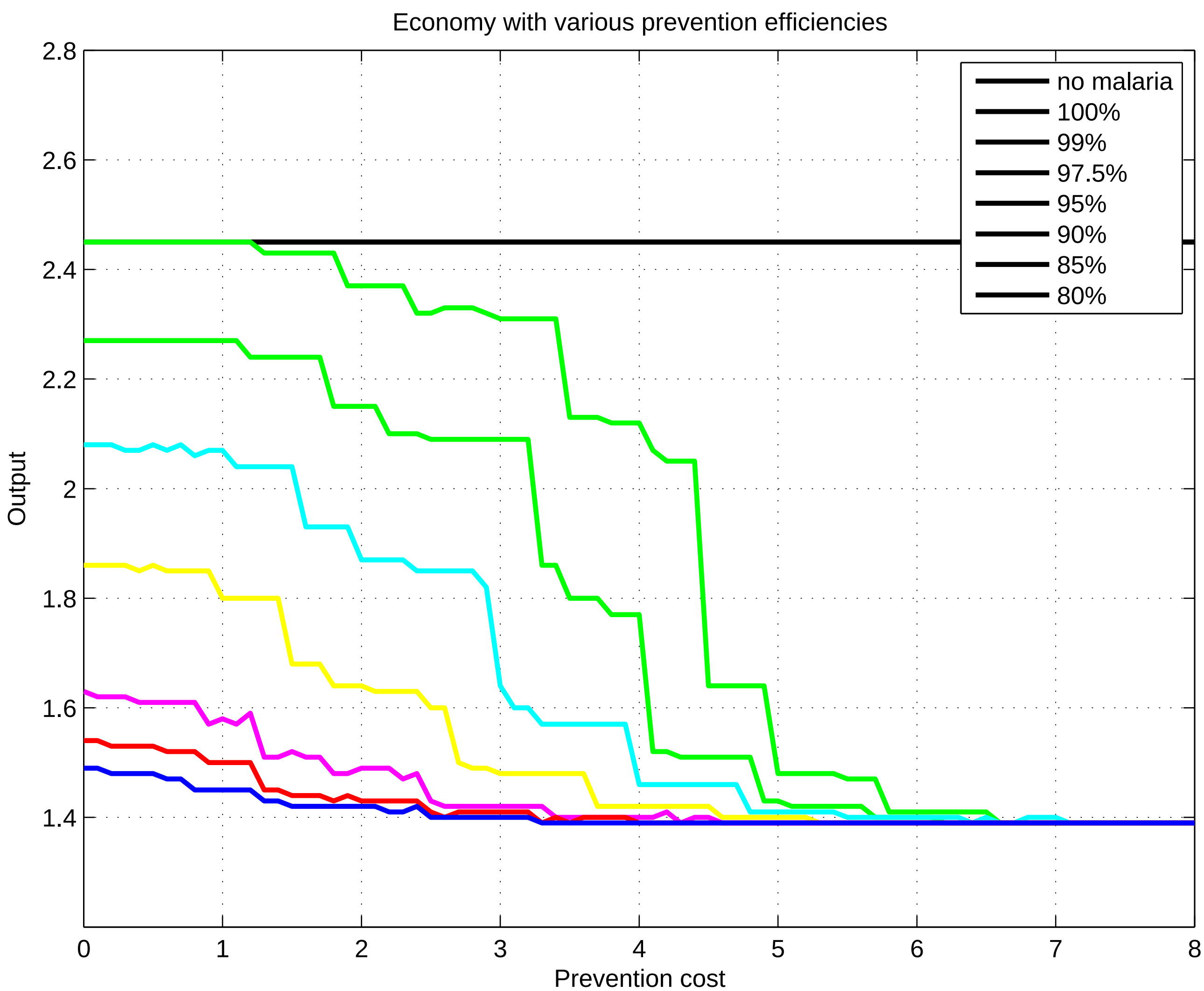
- **This does not mean that the international community should not mobilize to fight malaria; but we should be cautious in justifying such spending on the grounds that it will massively increase incomes in the developing world.**



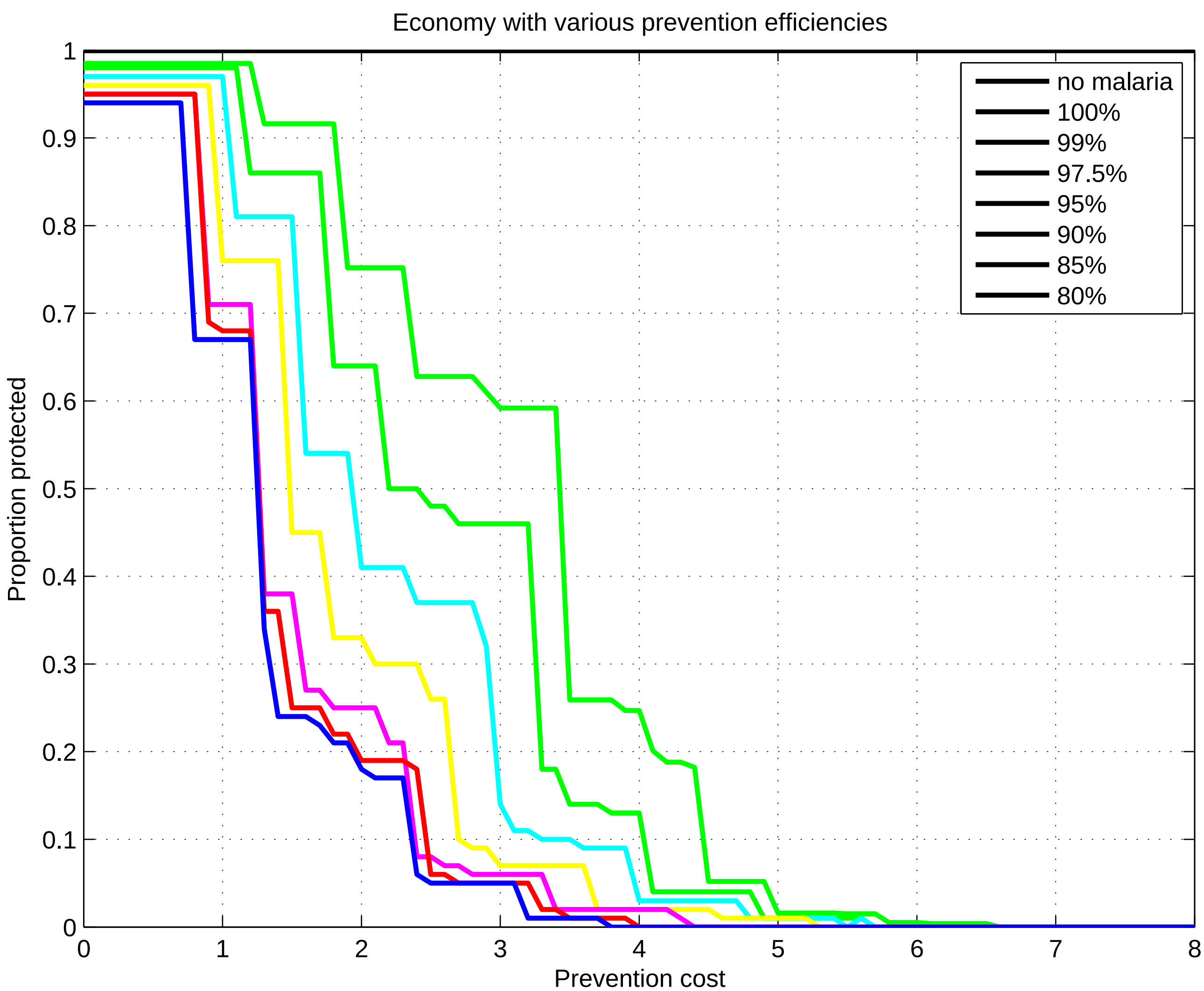
Output
Prevention cost
Consumption
Prevention cost
Capital
Prevention cost
Proportion sick, protected
Prevention cost



Subsistence consumption
Output
Prevention cost
0
0.25
0.5
0.75
Standard deviation of shocks
0.448
0.224
0
Productivity loss from sickness
0.25
0.1
0
Malaria ecology factor Z
0.5
0.7
0.9
Discount coefficient β
0.92
0.95
Elasticity of infection γ
0.244
0.122
0.061
Probability of death of sick
3%
4.5%
6%
7.5%
Consumption cost of sickness
10%
0%



Economy with various prevention efficiencies
no malaria
100%
99%
97.5%
95%
90%
85%
80%
Output
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
0
1
2
3
4
5
6
7
8
Prevention cost



Economy with various prevention efficiencies
Proportion protected
Prevention cost
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
1
2
3
4
5
6
7
8
no malaria
100%
99%
97.5%
95%
90%
85%
80%