Malaria in the Americas:
A Retrospective Analysis of Childhood Exposure*

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Abstract

This study considers the malaria-eradication campaigns in the United States (circa 1920), and in Brazil, Colombia and Mexico (circa 1955), with a specific goal of measuring how much childhood exposure to malaria depresses labor productivity. The eradication campaigns studied happened because of advances in medical and public-health knowledge, which mitigates concerns about reverse causality of the timing of eradication efforts. Data from regional malaria eradication programs are collected and collated with publicly available census data. Malarious areas saw large drops in their malaria incidence following the campaign. In both absolute terms and relative to non-malarious areas, cohorts born after eradication had higher income as adults than the preceding generation. Similar increases in literacy and the returns to schooling are observed. Results for years of schooling are mixed.

Keywords: Malaria, tropical disease, eradication.

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1 Introduction

The disease known as malaria, a "scourge of mankind" through history, persists in tropical countries up to the present day. These same tropical areas have, generally speaking, a much lower level of economic development than that enjoyed in the temperate climates. These facts lead us to a natural question: does malaria hold back economic progress?

The simple correlation between tropical disease and productivity cannot answer this question. Malaria might cause underdevelopment, but the failure to eradicate malaria might equally well be a symptom of underdevelopment. Indeed, tropical countries also tend to have "debilitating" institutions, such as the poor protection of property rights and weak rule of law, the latter of which makes it difficult to marshal resources in support of public health. This important international question has an interesting parallel among regions within countries. For example, southern Mexico, the southern U.S., the *tierra caliente* of Colombia, and the north of Brazil have born a disproportionate burden of malaria infection in those countries, but these regions were also disproportionately host to colonial, extractive institutions for several centuries. Both factors plausibly play a role in the failure to eradicate malaria.

How can we cut through this Gordian knot of circular causality? The standard econometric answer is to consider plausibly exogenous variation in malaria. A possible source of such variation comes from targeted interventions in public health.

The present study considers two major attempts to eradicate malaria in the Americas during the Twentieth century. The first episode analyzed took place in the Southern United States, largely in the decade of the 1920s. During this period, a wealth of new knowledge about the malaria transmission mechanism was applied to the malaria problem in the South. The second episode is the worldwide malaria eradication campaign, and in particular as it was implemented in Colombia, Brazil, and Mexico (principally in the 1950s). The efforts to eradicate malaria worldwide were spurred on by the discovery of DDT, a powerful pesticide. After the World War II, the World Health Organization helped many afflicted countries put together programs of spraying to combat malaria transmission. The campaigns in these regions partially interrupted the malaria transmission cycle and brought about marked drops in infection in a relatively short period of time. (Further background on the disease and the eradication efforts is found in Section **??**.) Moreover, sufficient time has passed that we can evaluate the long-term consequences of eradication.

The relatively rapid impact of the treatment campaigns combine with cross-area heterogeneity to form the research design of the present study. These four countries are geographically variegated, such that, within each country, some regions have climates that support malaria transmissions, while other regions do not. Areas with high malaria infection rates had more to gain from eradication, but the non-malarious areas serve as a comparison group, filtering out common trends in national policy, for example. Moreover, the reduction in disease burden occur in the space of a few years, and resulted from critical innovations to knowledge and spending, and these innovations came largely from outside the studied areas. This latter fact mitigates the usual concern about policy endogeneity.

A further goal of this study is identify the role that childhood exposure to malaria plays in subsequent labor productivity as an adult. While direct effects of malaria on adults can be partially measured with lost wages from work absences and mortality, little is known about effects that persist over the life cycle. Children are more susceptible to malaria than adults, most likely because prolonged exposure to the disease bring some degree of resistance. But while partial immunity is conferred by age, the damage from childhood exposure to malaria may be hard to undo: most of a person's human-capital and physiological development happen in childhood.

I show in Section 4 that childhood exposure to malaria is indeed related to lower income as an adult. Using census microdata, I compare the socioeconomic outcomes of cohorts born well before the campaigns to those born afterwards. In both absolute terms and relative to the comparison group of non-malarious areas, cohorts born after eradication had higher income and were more literate. Mixed results are found for years of schooling, consistent with the economic theory of schooling (which compares returns with opportunity costs).

This result is not sensitive to accounting for a variety of alternative hypotheses. I obtain essentially similar estimates of malaria coefficients even when controlling for several indicators of health and economic development. Moreover, I show in Section 5 that the shift in the malaria-income relationship coincides with childhood exposure to the eradication efforts, and not with a trend or autoregressive process. I also find a relative increase in the returns to schooling associated with malaria eradication.

2 Malaria and the Eradication Campaigns

[TO COME: (A) NARRATIVE OF MEDICAL AND TECHNOLOGICAL ADVANCES (B) DESCRIPTION OF THE CAMPAIGNS]

2.1 Research Design

The first factor in the research design is that the commencement of eradication was substantially due to factors external to the affected regions. The eradications were due to critical innovations to knowledge from outside the areas. This contrasts with explanations that might have potentially troublesome endogeneity problems, such as, for example, positive income shocks in the endemic regions. Such innovations were not related to or somehow in anticipation of the future growth prospects of the affected areas, and therefore should not be thought of as endogenous in this context.

Second, the anti-malaria campaigns achieved considerable progress against the disease in less than a decade. This is a sudden change on historical time scales, especially when compared to trend changes in mortality throughout recent history, or relative to the gradual recession of malaria in the Midwestern US or Northern Europe. Moreover, I examine outcomes over a time span of 60 to 150 years of birth, which is unquestionably long relative to the malaria eradication campaigns.

The final element in the identification strategy is that different areas within each country had distinct incidences of malaria. In general terms, this meant that the residents of the US South, southern Mexico, northern Brazil, and lowland Colombia were relatively vulnerable to infection.[1] Populations in areas with high (pre-existing) infection rates were in a position to benefit from the new treatments, whereas areas with low endemicity were not. This cross-regional difference permits a treatment/control strategy.

The advent of the eradication effort combines with the cross-area differences in pre-treatment malaria rates to form the research design. The variable of interest is the pre-eradication malaria intensity. By comparing the cross-cohort evolution of outcomes (e.g., adult income) across areas with distinct infection rates, one can assess the contribution of the eradication campaigns to the observed changes. (Specific estimating equations are presented below.)

How realistic is the assumption that areas with high infection rates benefited more from the eradication campaign? Mortality and morbidity data indicate drops of fifty to eighty percent in the decade following the advent of the eradication efforts. Figure 1 presents data on this issue. Such a dramatic drop in the region's average infection rate, barring a drastic reversal in the pattern of malaria incidence across the region, would have had the supposed effect of reducing infection rates *more* in highly infected areas than in areas with moderate infection rates. The decline in malaria incidence as a function of intensity prior to the eradication campaign is found in Figure 2.[2] The basic assumption of this section — that areas where malaria was highly endemic saw a greater drop

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[1] Humid areas with slow-moving water were the preferred nursery for mosquitoes, the vector that transmits malaria.

[2] This figure embodies the first-stage relationship. Consider the aggregate first-stage equation:

$$M_{jt} = \gamma + \delta_j + \delta_t + \eta_{jt}$$

For area j in ear t. This equation can be written in first-differenced form and evaluated in the post-campaign period:

$$\Delta M_j^{post} = \gamma M_j^{pre} + \text{constant} + \nu_{jt},$$

in infection than areas with low infection rates — is born out across areas in the countries where data are available.

3 Data Sources and Definitions

The micro-level data employed in the present study come from the *Integrated Public Use Micro Sample* (IPUMS), a project to harmonize the coding of census microdata from the United States and several other countries (Ruggles and Sobek (1997)). I analyze the census data from the United States, Brazil, Colombia and Mexico.

The geographic units employed in this analysis are place of birth rather than current residence. Matching individuals with malaria rates of the area where they end up as adults would then be difficult to interpret because of selective migration. Instead, I use the information on malaria intensity in an individual's area of birth to conduct the analysis. For the U.S., Mexico and Brazil, this means the state of birth. The Colombian census also contains information on birthplace by *municipio*, a second-order administrative unit similar to U.S. counties.

For the United States, the base sample consists of native-born white males in the *Integrated Public Use Micro Sample* or IPUMS (Ruggles and Sobek, 1997) and *North Atlantic Population Project* (NAPP, 2004) datasets between the ages of 25 and 55, inclusive, for the census years 1880-1990, which includes cohorts years of birth ranging from 1825 to 1965. I use two proxies for labor productivity that are available for a large number of Censuses. The occupational income score and Duncan socioeconomic index are both average indicators by disaggregated occupational categories that were calibrated using data from the 1950 Census. The former variable is the average by occupation of all reported labor earnings. The measure due to Duncan (1961) is instead a weighted average of earnings and education among males within each occupation. Both variables can therefore measure shifts in income that take place between occupations. The Duncan measure has the added benefit of picking up between-occupation shifts in skill requirements for jobs. Occupation has been measured by the Census for more than a century, and so these income proxies are available for a substantial stretch of cohorts.

The data on native-born males from the Brazilian and Mexican IPUMS-coded censuses from 1960 to 2000 are similarly pooled, resulting in birth cohorts from 1905 to 1975. These censuses contain questions on literacy, years of education and income. I also construct an income score based on occupation and industry to better compare with the US results.

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an equation that relates the observable variables graphed in Figure 2.

For Colombia, I use the IPUMS microdata on native males from the censuses of 1973 and 1993 (those for which municipio of birth was available). This yields birth cohorts from 1918 to 1968. I use the census-defined variables for literacy and years of schooling. I also use the income score defined from the Mexican and Brazilian data.

I combine microdata from various censuses to construct panels of average outcomes by cohort. Cohorts are defined by both when they were born and where they were born. To construct these panels, I pool the micro-level census data. The individual-level outcomes in the microdata are projected on to dummies for year-of-birth × census year × country. (Cohorts can appear in multiple censuses in this pooling strategy.) I then take the average residual from this procedure for each cell defined by period of birth and state (or municipio in the case of Colombia) of birth. For Section 4, I compare cohorts born well before or just after the campaign, so the period of birth is defined by childhood exposure to the eradication campaigns. In Section 5, I consider how cross-area outcomes changes by year of birth, so the panels are constructed with year of birth × area of birth as the units of observation.

Malaria data are drawn from a variety of sources. United States data are reported in Maxcy (1924) and Vital Statistics (Census, 1933). Mexican data are drawn from Pesqueira (1957) and from the Mexican Anuario Estadístico (Dirección General de Estadística, 1960). SEM (1957) and the Colombian Anuario de Salubridad (DANE, 1970) are the sources for the Colombian data. Data on malaria ecology are derived from Mellinger et al. (1998) and Poveda et al. (199x). The ecology data were matched with states and municipios using GIS.

4 Pre/Post Comparisons

I compare changes in socioeconomic outcomes by cohort across areas with distinct malaria intensities, in order to assess the contribution of the eradication campaign to the observed changes. The basic equation to be estimated is

$$\Delta Y_{i,t} \;=\; \beta M_{i,t-1} \;+\; X_{i,t-1}\Gamma \;+\; \alpha \;+\; \varepsilon_{i,t}$$

in which Y is some socioeconomic outcome for state or municipio i. The time subscript t refers to a year of birth following the malaria-eradication campaign, while $t-1$ indicates being born (and having become an adult) prior to advent of the campaign. The pre-program malaria incidence is $M_{i,t-1}$, the X variables are a series of controls, and α is a constant term. The parameter of interest is β. This parameter can be thought of as coming from a reduced-form equation, in the sense of two-stage least squares.[3]

Areas in the US with higher malaria burdens prior to the eradication efforts saw larger cross-cohort growth rates in income, as measured by the occupational proxies. These results are found in Table 1. Panel A contain estimates for the basic specification of equation 4, plus a dummy for being born in the South. If the oldest cohorts had high malaria infection and low productivity because of some mean-reverting shock, we might expect income gains for the subsequent cohorts even in the absence of a direct effect of malaria on productivity. I control for the natural logarithm of state wages by using data on labor earnings by state in 1899 from Lebergott (1964). Panel B contains the basic mean-reversion control, while Panel C includes a more flexible control for wages. Panel D controls for additional measures of health, while Panel E includes controls for fraction urban and black, and for the 1930 unemployment rate. Panel F contains controls for changes in educational policy and pre-existing literacy rates, while Panel G includes all of the above control variables simultaneously in the specification. The estimates for malaria are not substantially affected by the inclusion of these additional variables. Figure 3 displays a scatter plot of the orthogonal component of cross-cohort income growth versus malaria, after having projecting each variable onto the control variables.

Table 2 reports the estimates for Mexico and Brazil. Malarious areas saw faster cross-cohort growth in income and literacy, but mixed evidence on years of schooling. Panel A contains the results from the basic specification containing just malaria and country effects. Panel B includes a variety of controls variables, including sectoral mix, infant mortality, and proxies for economic development. Figure 4 displays the orthogonal component of malaria and changes across cohort in these outcomes.

Results from Colombia indicate that childhood exposure to malaria suppressed income. Cross-

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[3] The model is derived as follows. Consider an individual i, in area j, with year-of-birth t, we start with an individual-level model with individual infection data and linear effects of malaria:

$$Y_{ijt} = \alpha M_{ijt} + \delta_j + \delta_t + \tilde{\varepsilon}_{ijt}$$

where M_{ijt} is a measure of childhood malaria infection. No data set has both childhood malaria infection data and adult income, and the research design is fundamentally at the period-of-birth × area-of-birth level, so I rewrite the equation above in aggregate form:

$$Y_{jt} = \tilde{\alpha} M_{jt} + \delta_j + \delta_t + \tilde{\varepsilon}_{jt}^{'}$$

I partition the cohorts into those born after the advent of the campaign and those who were already adults by the time the campaign started. I then difference the model along these lines, and take $M_{i,t-1}$ as an instrument for the decline in malaria. The resulting reduced form of this system is equation 4. Alternatively, one could have written the individual-level model with separate terms for individual and aggregate infection variables, the latter of which reflecting some spillover from peer infection to own human capital. But both of these effects would be subsumed into the $\tilde{\alpha}$ coefficient on the ecological infection rate, and it is this composite coefficient that I seek to measure in the present study.

cohort growth in income, literacy and education was higher in the areas with more perverse malaria ecology, as shown in Table 3. These estimates are robust to including a variety of controls for sectoral mix, violence, and proxies of economic development. The residualized components of the cross-cohort changes and malaria ecology are shown in Figure 5.

5 Cohort-Specific Results

The shift in the malaria-income relationship coincides with childhood exposure to the eradication efforts. This can be seen graphically in this section. For each year of birth, OLS regression coefficients are estimated on the resulting cross section of states/municipios of birth. Consider a simple regression model of an average outcome, Y_{jk}, for a cohort with state of birth j and year of birth k:

$$Y_{jk} = \beta_k \ \mathrm{MI}_j + \delta_k + X_j \ \Gamma_k + \nu_{jk} \tag{1}$$

in which β_k is year-of-birth-specific coefficient on malaria, X_j is a vector of other state-of-birth controls,[4] and δ_k and Γ_k are cohort-specific intercept and slope coefficients. I estimate this equation using OLS for each year of birth k. This specification allows us to examine how the relationship between income and pre-eradication malaria ($\hat{\beta}_k$) differs across cohorts.

I start with a simple graphical analysis using this flexible specification for cross-cohort comparison. Figures 6, 7, and 8 display a plot of the estimated β_k, for the various countries under study. The x axis is the cohort's year of birth. The y axis for each graphic plots the estimated cohort-specific coefficients on the area-of-birth measure of malaria. Each cohort's point estimate is marked with a dot.

Results for the US are shown in Figure 6, which displays the coefficient on state-of-birth 1890 malaria mortality for each year of birth. The additional variable in the summarized regressions are the various control variables from Table **??**, Panel G.

To consider the effects of childhood exposure to malaria, observe that cohorts that were already adults in 1920 were too old to have benefited from the eradication efforts during childhood. On the other hand, later cohorts experienced reduced malaria infection during their childhood. This benefit increased with younger cohorts who were exposed to the anti-malaria efforts for a greater fraction of their childhood. The dashed lines therefore measure the number of years of potential childhood exposure[5] to the malaria-eradication campaign. (The line is rescaled such that pre-1890

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[4] These additional controls are used in constructing the ultimate panels of Tables **??**, **??**, and **??**.

[5] Specifically, the formula is $\mathrm{Exp}_k = \max(\min(21, k - (1920 - 21)), 0)$, which treats 1920 as an approximate start date for exposure.

and post-1940 levels match those of the $\hat{\beta}_k$. The exposure line is not rescaled in the x dimension.) Cohorts born late enough to have been exposed to eradication during childhood generally have higher income than earlier cohorts, and this shift correlates with higher potential exposure to the eradication campaign.

In the Latin American samples, the malaria-related change in outcomes across cohorts coincides roughly to childhood exposure to the campaigns, rather than a pre-existing trend. Figures 7 and 8 display these results for Mexican and Brazilian states, and Colombian municipios, respectively. In each case, a trend break is evident approximately for those cohorts who were born just late enough to be exposed to the eradication campaign during some of their childhood. (Because the campaigns had their effect over a decade or more, the childhood-exposure measure represents an optimistically fast guess.)

Finally, I show that, for cohorts exposed to the campaign as children, the returns to schooling rose differentially for those born in malaria-prone areas. These results are shown in Figure 9 Each point is a cohort-specific regression coefficient on the interaction of malaria ecology (in the area of birth) with years of schooling. The specifications have income as the dependent variable, measured as log income in Mexico and Brazil (Panel A) and as the income score in Colombia (Panel B). To insure that nonlinear returns to schooling do not contaminate these results, the specification includes a full set of dummies for years of schooling interacted with census year. Fixed effects for year of birth × birthplace × census year are also included. The response for Mexico and Brazil appears best characterized by a trend break, while the pattern for Colombia more closely resembles the line for childhood exposure to the campaign.

6 Conclusions

This study considers the socioeconomic impact of the malaria-eradication campaigns in the United States (circa 1920), and in Brazil, Colombia and Mexico (circa 1955). The goal is to measure how much childhood exposure to malaria depresses labor productivity.

Several factors combine to form the research design. The eradication campaigns studied happened because of advances in medical and public-health knowledge, which mitigates concerns about reverse causality of the timing of eradication efforts. Highly malarious areas saw large drops in their malaria incidence following the campaign. Furthermore, these gains against the disease were realized in approximately a decade. Data from regional malaria eradication programs are collected and collated with publicly available census data.

In both absolute terms and relative to the comparison group of non-malarious areas, cohorts born after eradication had higher income as adults than the preceding generation. Similar increases in literacy and the returns to schooling are observed. Mixed results are found for years of schooling, consistent with the economic theory of schooling (which compares returns with opportunity costs).

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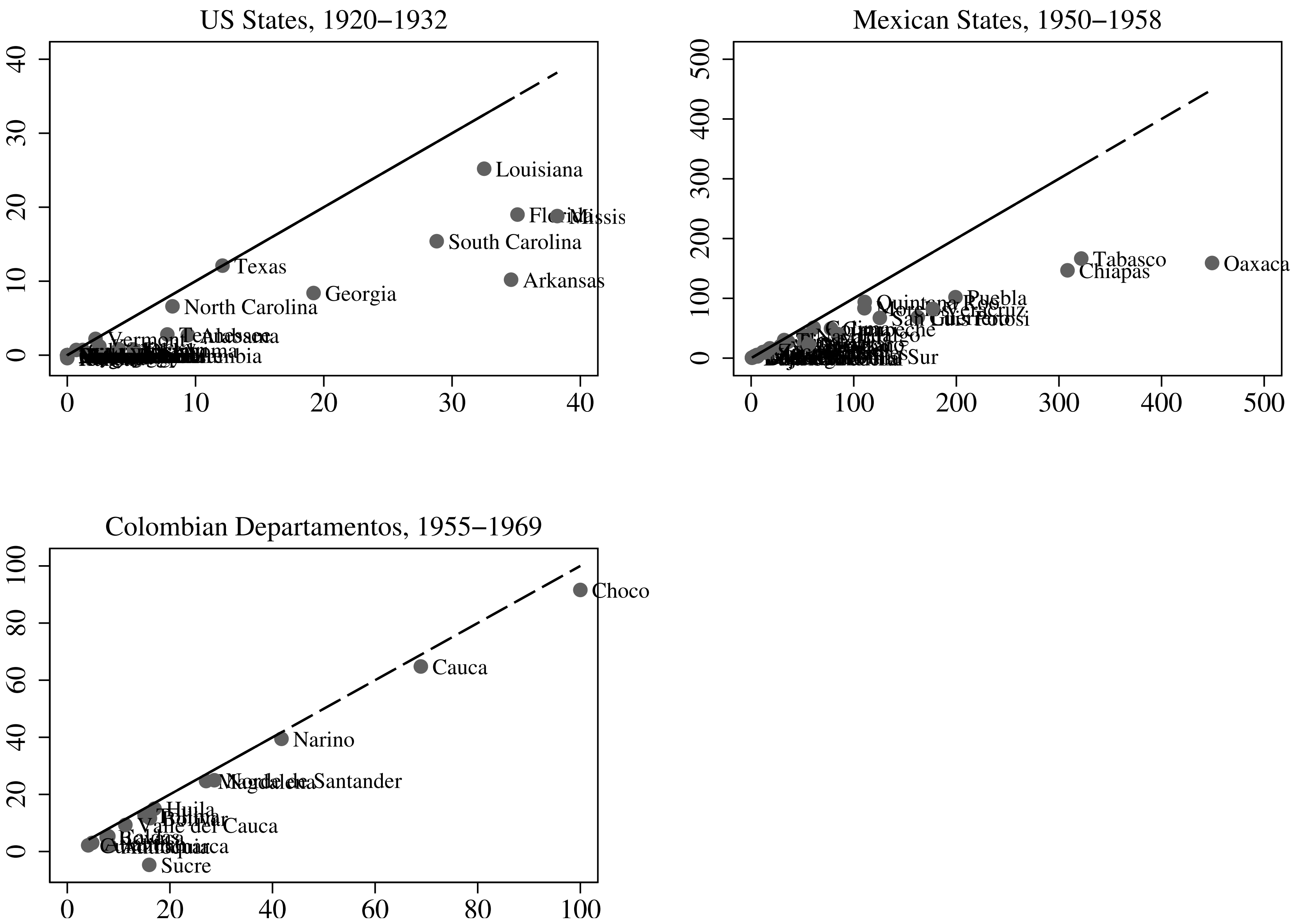
Figure 1: Malaria Incidence Before and After the Eradication Campaigns

Panel A: Mortality per Capita, Southern United States

Panel B: Cases Notified per Capita, Colombia

Figure 2: Highly Infected Areas Saw Greater Declines in Malaria



US States, 1920–1932

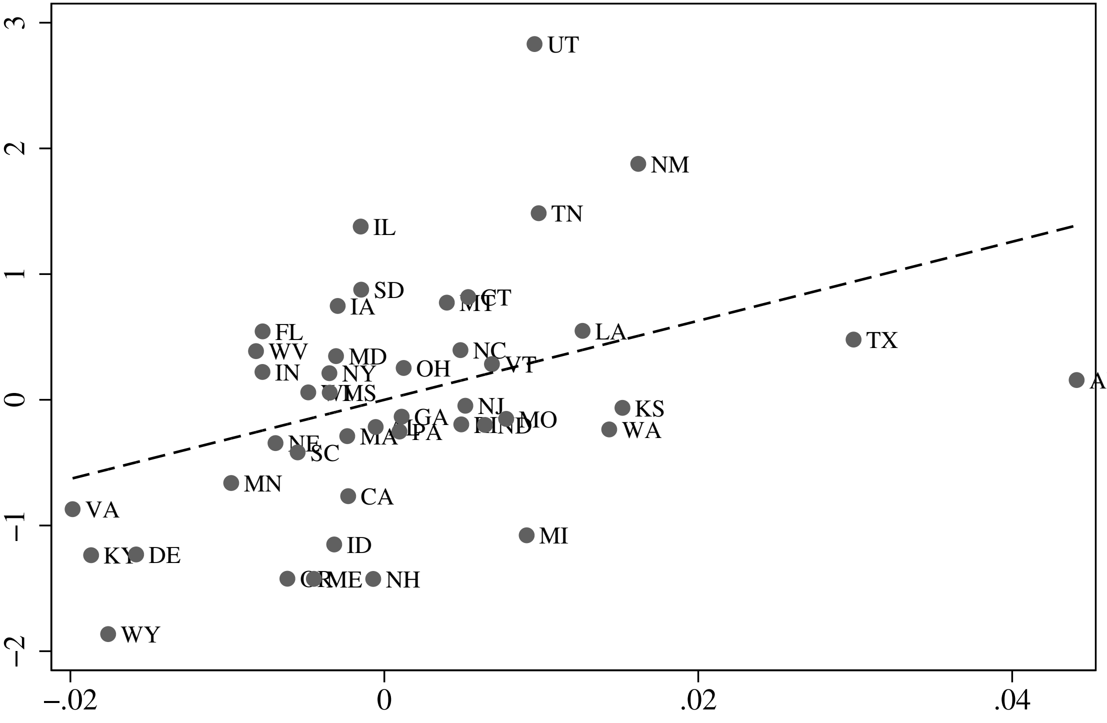
Mexican States, 1950–1958

Colombian Departamentos, 1955–1969

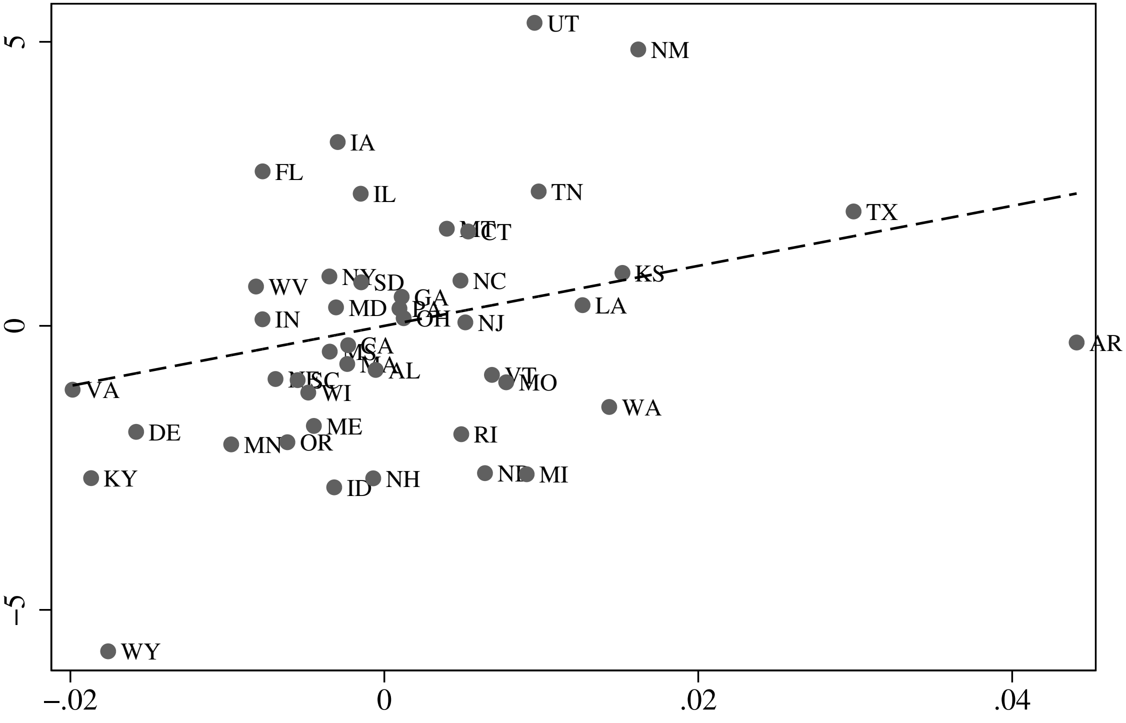
Notes: The y axis displays the estimated decrease in malaria mortality post-intervention. The x axis is the pre-campaign malaria mortality rate. The 45-degree line represents complete eradication. Both variables are expressed per 100,000 population. United States data are reported in Maxcy (1924) and Vital Statistics (Census, 1933). Mexican data are drawn from Pesqueira (1957) and from the Mexican Anuario Estadistico (Dirección General de Estadística, 1960). SEM (1957) and the Colombian Anuario de Salubridad (DANE, 1970) are the sources for the Colombian data.

Figure 3: Cross-Cohort Growth Rates versus Malaria: US States

Panel A: Change in Occupational Income Score

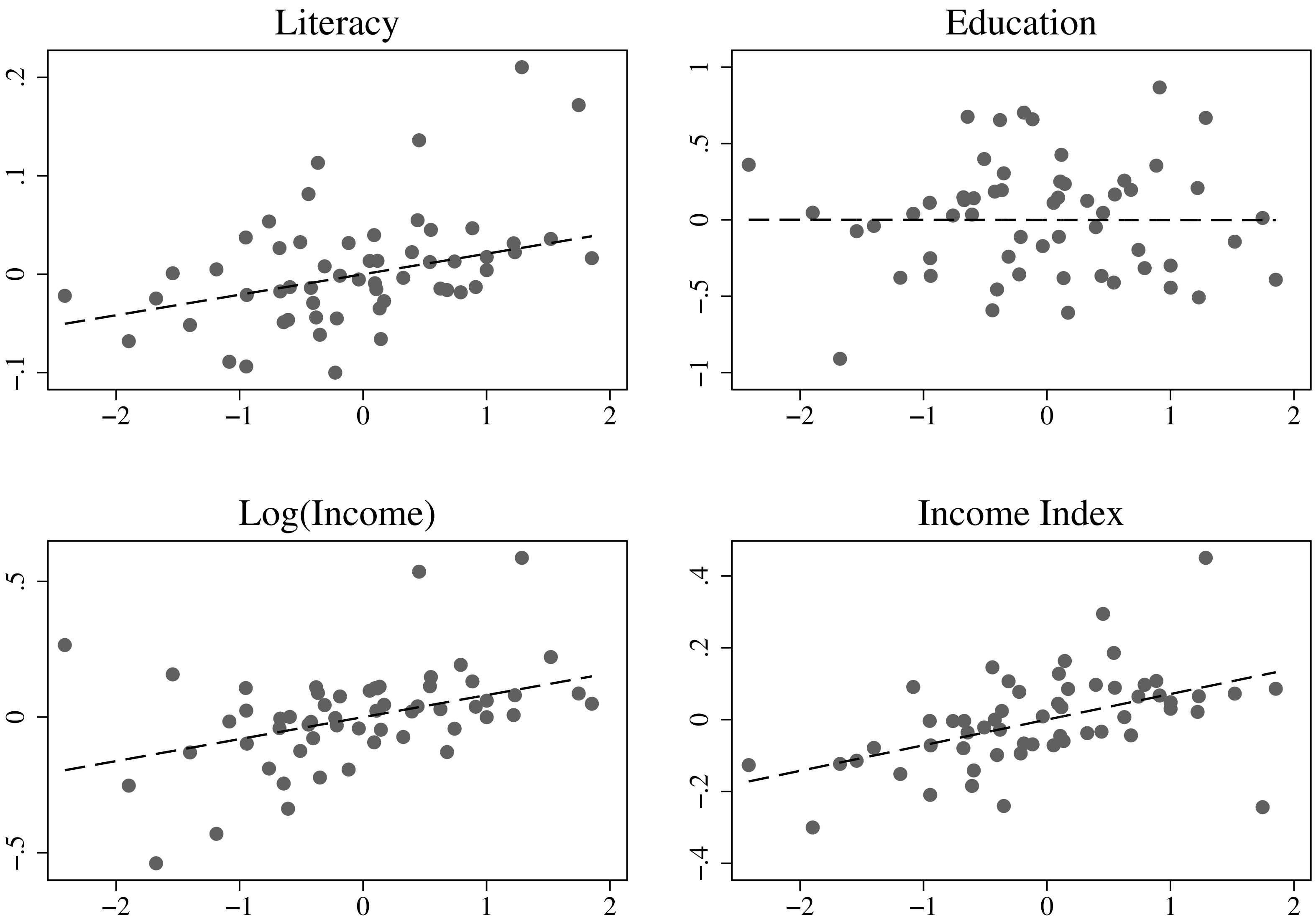


Panel B: Change in Duncan Socio-Economic Indicator



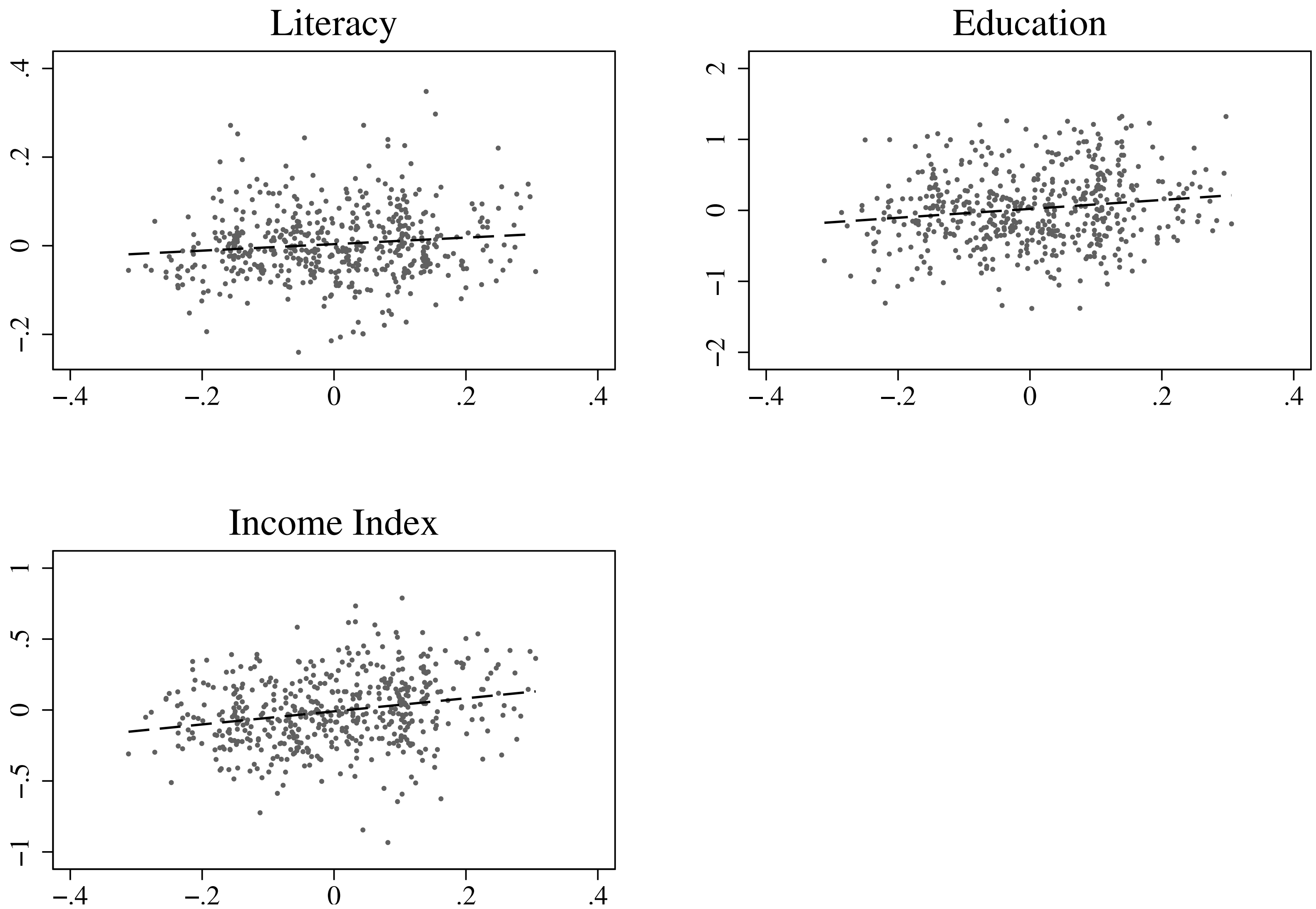
Notes: Top panel displays results for the occupational income score, while the bottom panel uses the Duncan Socioeconomic Indicator. The y-axis are the changes in the indicated income proxy between cohorts born before 1895 and those born after 1925. The x-axis plots malaria mortality over total deaths in 1890. Both variables are residuals from having projected the original data on to a dummy for South, a 4th-order polynomial for Lebergott 1899 wage series, child-mortality rate in 1890, urbanization in 1910, adult literacy in 1910, doctors per capita in 1898, state public health spending in 1898, hookworm infection circa 1917, fraction black in 1910, unemployment rate in 1930, and the log change from 1905-25 in school-term length, pupil/teacher ratio, and teacher salary.

Figure 4: Cross-Cohort Growth Rates versus Malaria: States in Mexico and Brazil



Notes: The y-axis are the changes in the indicated socioeconomic variable between cohorts born before 1940 and those born after 1957. The x-axis plots Mellinger measure of malaria ecology. Both variables are residuals from having projected the original data on to the controls used in Table 2, Panel B.

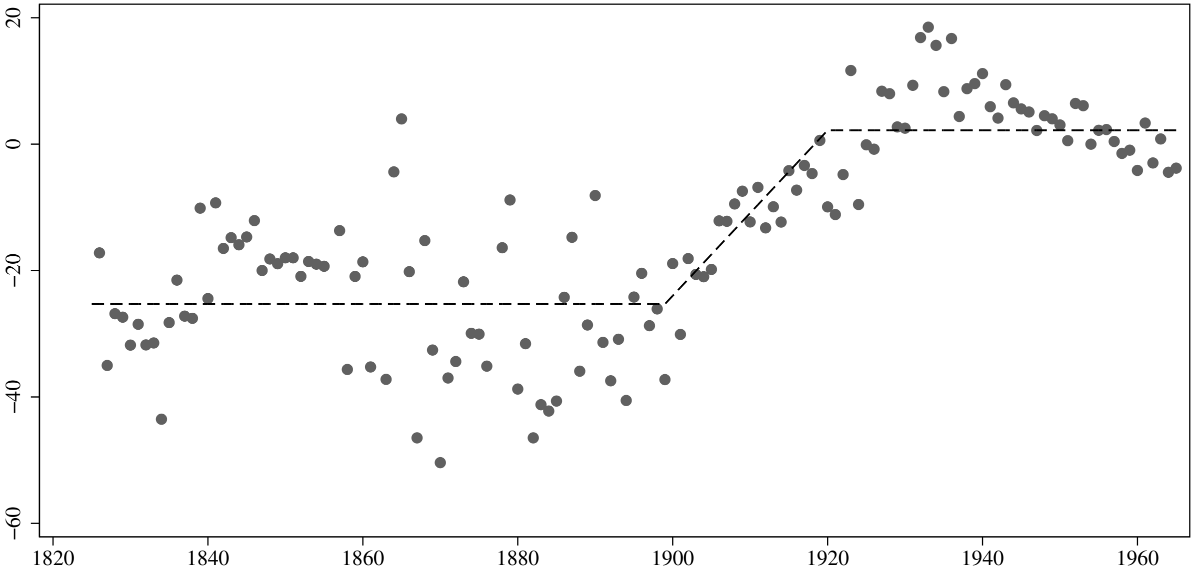
Figure 5: Cross-Cohort Growth Rates versus Malaria: Municipios in Colombia



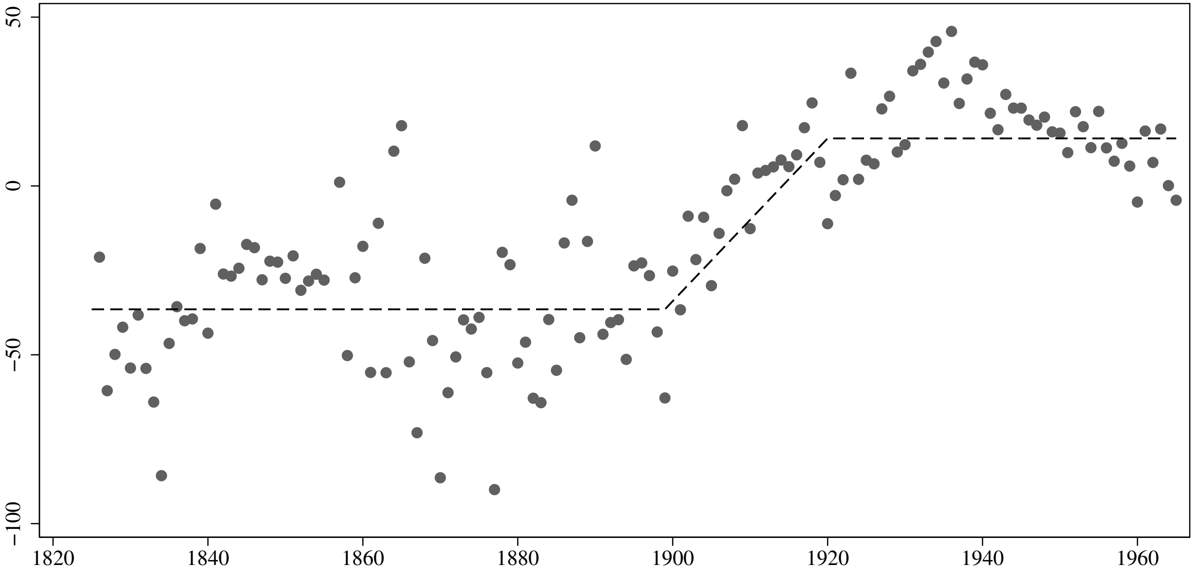
Notes: The y-axis are the changes in the indicated socioeconomic variable between cohorts born before 1940 and those born after 1957. The x-axis plots Poveda measure of malaria ecology. Both variables are residuals from having projected the original data on to the controls used in Table 3, Panel B.

Figure 6: Cohort-Specific Relationship: US States

Panel A: Occupational Income Score

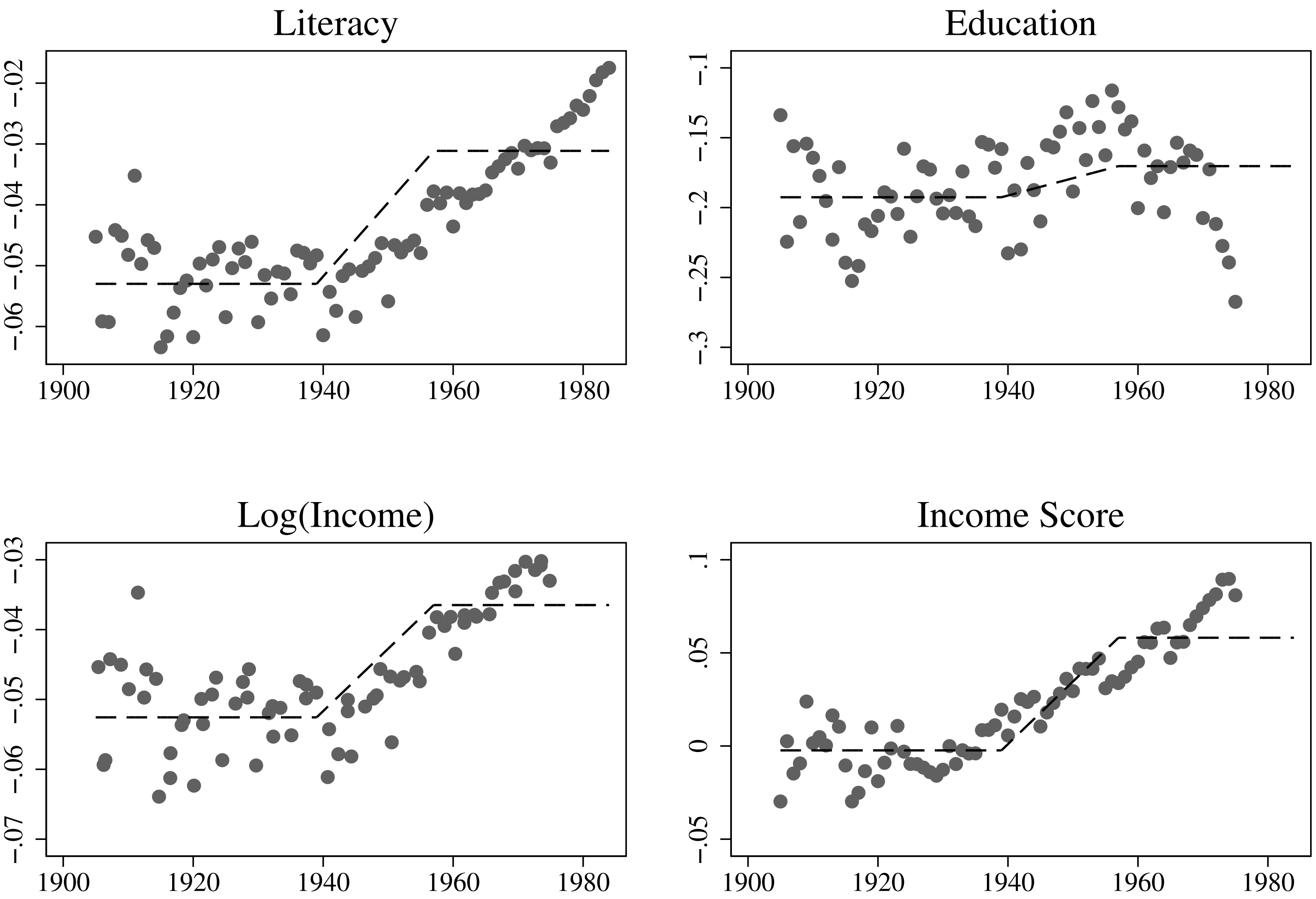


Panel B: Duncan Socio-Economic Indicator



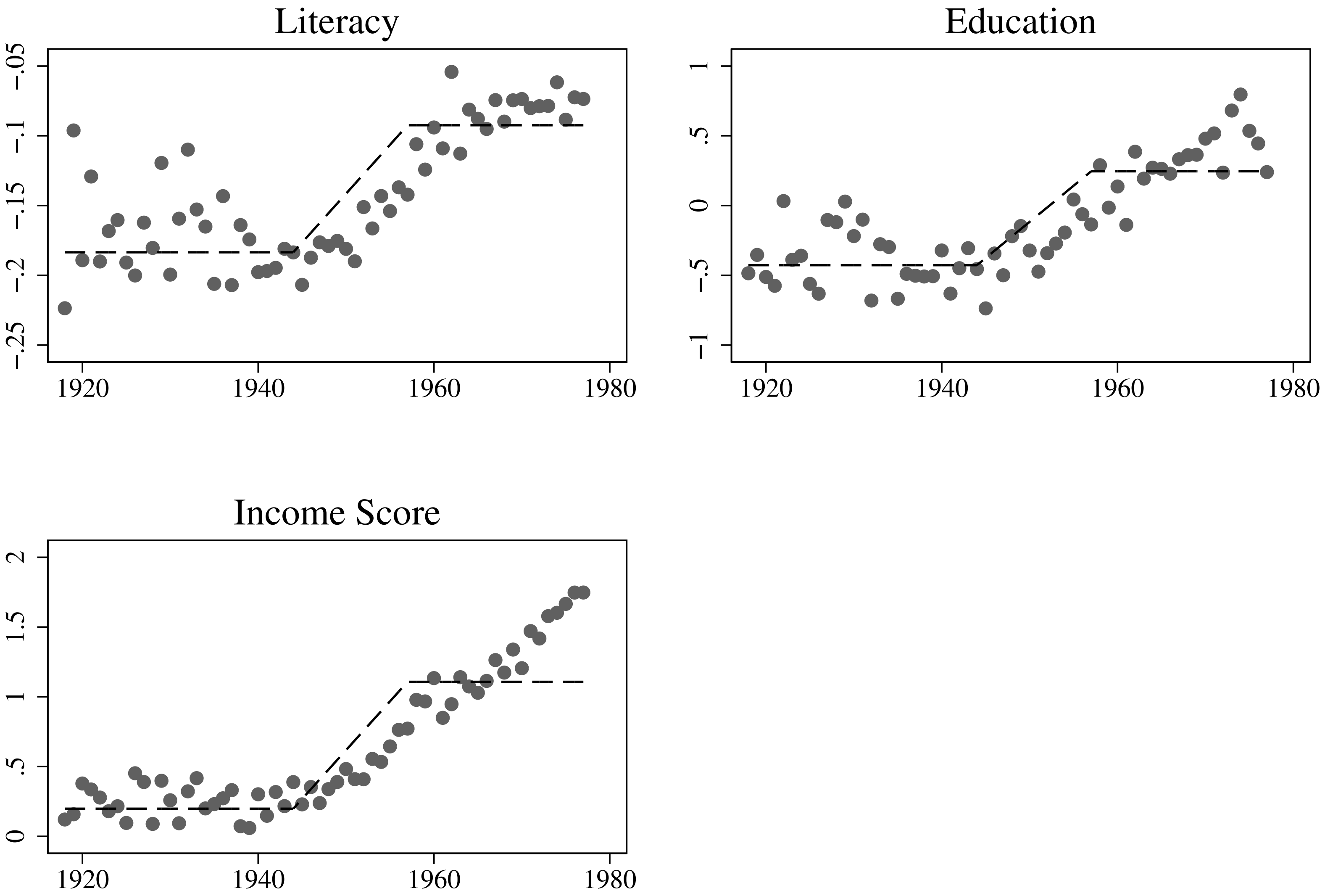
Notes: These graphics summarize regressions of income proxies on pre-eradication malaria-mortality rates (measured by the Census in 1890). The y axis for each graphic plots the estimated cohort-specific coefficients on the state-level malaria measure. The x axis is the cohort's year of birth. Each cohort's point estimate is marked with a dot. The dashed lines measure the number of years of potential childhood exposure to the malaria-eradication activities in the South. For the underlying regressions, the dependent variables are constructed from the indicated income proxies (the Duncan Socioeconomic Indicator and the Occupational Income Score). The base sample consists of native-born males in the IPUMS and NAPP datasets between the ages of 25 and 55, inclusive, for the census years 1880-1990, which results in year-of-birth cohorts from 1825 to 1965. The individual income proxies are projected on to dummies for year-of-birth × Census year observed (cohorts can appear up to four times in this design), and the residuals are averaged by year of birth and state of birth. For each year-of-birth cohort, OLS regressions coefficients are estimated on the resulting cross section of states of birth. In the basic specification, this state-of-birth average residual is regressed on to hookworm infection, Lebergott's measure of 1899 wage levels, and a dummy for the Southern region. The "full controls" specification contains, in addition, the various control variables from Table 1, Panel G.

Figure 7: Cohort-Specific Relationship: States in Mexico and Brazil



Notes:

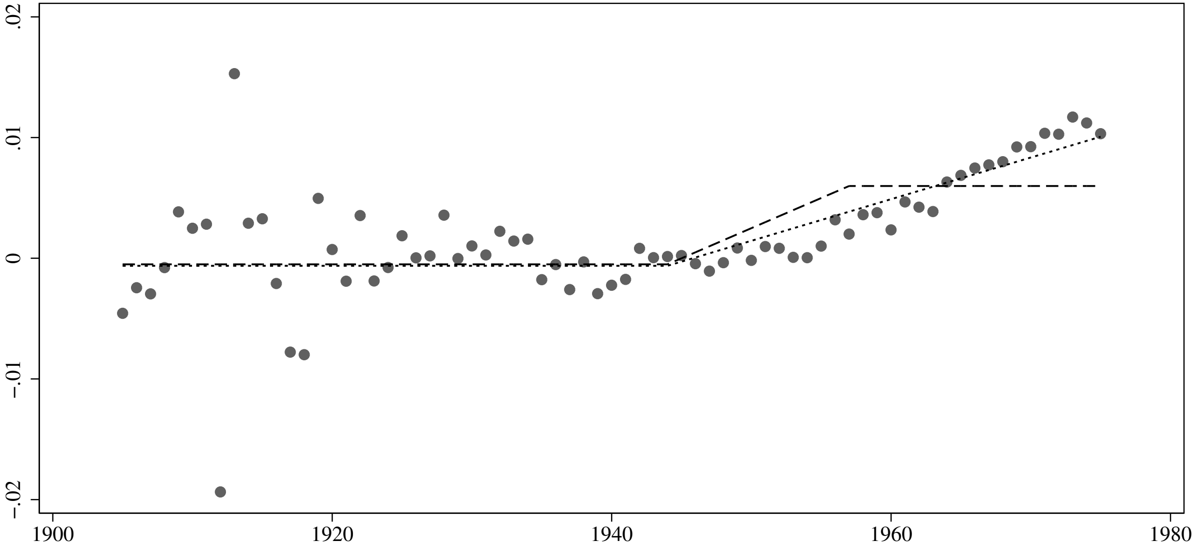
Figure 8: Cohort-Specific Relationship: Municipios in Colombia



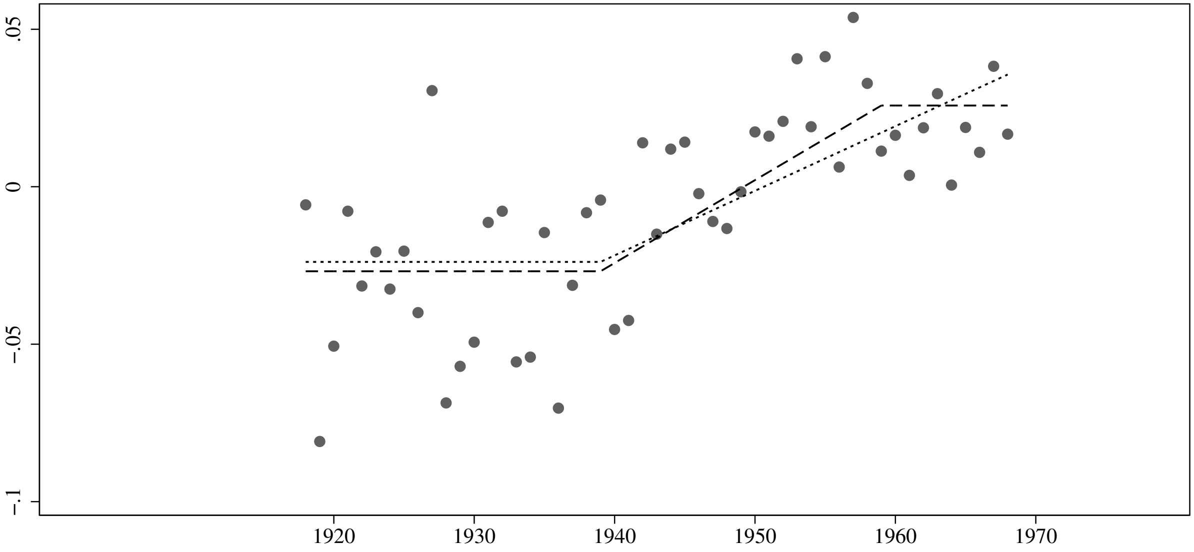
Notes:

Figure 9: Malaria and the Return to Schooling, By Year of Birth

Panel A: States in Mexico and Brazil



Panel B: Municipios in Colombia



Notes: Each point is a cohort-specific regression coefficient on the interaction of malaria ecology (in the municipio of birth) with years of schooling. The specification has the income index as a dependent variable and includes a full set of dummies for educational attainment interacted with census year. A full set of dummies for year of birth × birthplace × census year are also included.

Table 1: Basic Results for the United States

	Dependent Variables: Differences across Cohorts in...	
	Occupational Income Score	Duncan's SEI
Independent Variables:		
	Panel A: Basic Results	
Malaria / Total Mortality, 1890	37.686 ***	60.899 ***
	(11.036)	(21.476)
	Panel B: Control for Wage Differences	
Malaria / Total Mortality, 1890	37.927 ***	60.316 ***
	(11.101)	(21.311)
Wage Level, 1899 (Lebergott)	0.000	-0.001
	(0.001)	(0.001)
	Panel C: Wage as 4th-order polynomial	
Malaria / Total Mortality, 1890	36.617 ***	55.824 ***
	(10.763)	(19.909)
	Panel D: Health Controls	
Malaria / Total Mortality, 1890	33.897 ***	63.480 ***
	(9.733)	(20.610)
Child mortality rate, 1890	-0.009 **	0.002
	(0.004)	(0.007)
Doctors per capita, 1898	0.000	0.003 **
	(0.001)	(0.002)
State public health spending per capita, 1898	-0.005 *	-0.007
	(0.003)	(0.007)
Hookworm infection rate, c. 1917	3.540 **	3.215 **
	(1.686)	(1.361)

Note: Table continues on next page.

Table 1 (Continued): Basic Results for the United States

	Dependent Variables: Differences across Cohorts in...	
Independent Variables:	Occupational Income Score	Duncan's SEI
	Panel E: Other Controls	
Malaria / Total Mortality, 1890	30.118 ***	45.827 **
	(11.400)	(18.134)
Fraction living in urban areas, 1910	-6.167 ***	-6.204 **
	(1.374)	(2.732)
Fraction black, 1910	0.967	6.063 **
	(1.664)	(2.882)
Unemployment rate, 1930	0.443 *	0.900 **
	(0.237)	(0.433)
	Panel F: Education Controls	
Malaria / Total Mortality, 1890	44.825 ***	59.306 **
	(12.240)	(23.279)
Adult literacy rate, 1910	8.839 *	-3.235
	(4.908)	(8.025)
Change, school term length, 1905-25	3.522	2.216
	(2.341)	(4.117)
Change, pupil/teacher ratio, 1905-25	1.613 *	2.850 *
	(0.883)	(1.717)
Change, teacher salary, 1905-25	1.542	0.224
	(1.381)	(2.728)
	Panel G: Include Controls Simultaneously	
Malaria / Total Mortality, 1890	33.392 **	59.257 **
	(13.844)	(29.103)

Notes: This table reports estimates of equation 4 using OLS. The units of observation are US states. The dependent variables are as indicated in the column headings. Robust (Huber-White) standard errors in parentheses. Single asterisk denotes statistical significance at the 99% level of confidence; tilde at the 95% level. Reporting of constant term suppressed. Unexposed cohorts are those born before 1940 and fully exposed cohorts are those born after 1960. Cohorts are determined based on state of birth. The universe for the base sample consists of the native-born population between the ages of 25 and 55 (15–55 for literacy) in the 1960–2000 census microdata from the IPUMS.

Table 2: Basic Results for Mexico and Brazil

	Dependent Variables: Differences across Cohorts			
	Literacy	Education	Log Income	Income Index
Independent Variables:				
		Panel A: Basic Results		
Malaria Ecology (Mellinger)	0.020 ***	-0.127 ***	0.115 ***	0.050 ***
	(0.005)	(0.033)	(0.013)	(0.011)
		Panel B: Results with Controls		
Malaria Ecology (Mellinger)	0.017 ***	-0.003	0.084 ***	0.050 ***
	(0.006)	(0.044)	(0.023)	(0.016)
Population Density	0.016 ***	0.013	-0.004	0.035 *
	(0.005)	(0.057)	(0.026)	(0.020)
Fraction Urban	-0.115	-1.339	-0.491	0.335
	(0.142)	(1.206)	(0.513)	(0.284)
Infant Mortality	-0.030 **	-0.235	0.198 ***	0.035
	(0.014)	(0.157)	(0.067)	(0.044)
Fraction Economically Activ	-0.219	1.754	-2.837 ***	-0.499
	(0.372)	(3.113)	(1.012)	(0.978)
Log(Electricity Consumptio	-0.002	0.022	0.003	0.012
	(0.005)	(0.042)	(0.017)	(0.011)
Fraction of Employment in...				
Agriculture	0.766	7.298	0.172	2.463
	(0.776)	(6.507)	(2.663)	(1.644)
Extractive Industries	0.690	5.238	0.731	3.202 *
	(0.808)	(6.492)	(2.748)	(1.711)
Manufacturing	0.819	8.298	1.236	1.869
	(0.764)	(6.627)	(2.783)	(1.547)
Transportation	0.716	22.337 ***	0.862	4.750 *
	(1.047)	(8.234)	(3.215)	(2.552)
Services	1.000	8.125	0.323	3.117 *
	(0.886)	(6.408)	(3.079)	(1.839)
Other sectors	-0.115	12.616	-0.250	1.433
	(0.948)	(8.552)	(4.225)	(2.269)

Notes: This table reports estimates of equation 4 using OLS. The units of observation are Mexican and Brazilian states. The dependent variables are as indicated in the column headings. Robust (Huber-White) standard errors in parentheses. Single asterisk denotes statistical significance at the 99% level of confidence; tilde at the 95% level. Reporting of constant term suppressed. Unexposed cohorts are those born before 1940 and fully exposed cohorts are those born after 1960. Cohorts are determined based on state of birth. The universe for the base sample consists of the native-born population between the ages of 25 and 55 (15–55 for literacy) in the 1960–2000 census microdata from the IPUMS.

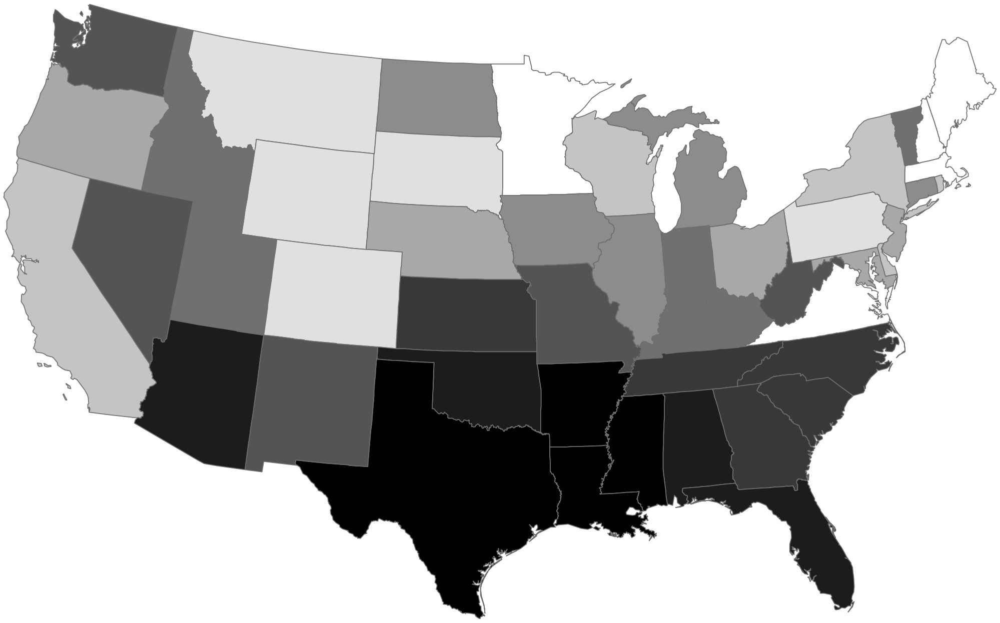
Table 3: Basic Results for Colombia

	Dependent Variables: Differences across Cohorts		
Independent Variables:	Literacy	Education	Income Index
Panel A: Basic Results			
Malaria Ecology (Poveda)	0.058 **	0.605 ***	0.372 ***
	(0.025)	(0.152)	(0.091)
Panel B: Results with Controls			
Malaria Ecology (Poveda)	0.059 **	0.402 **	0.441 ***
	(0.025)	(0.184)	(0.085)
“La Violencia”, before 1955	0.006 **	0.014	-0.011
	(0.003)	(0.024)	(0.009)
“La Violencia”, 1955 and after	0.000	0.037 **	0.008
	(0.002)	(0.016)	(0.006)
High Concentration “Minifundista”	-0.004	-0.054	-0.029
	(0.007)	(0.054)	(0.026)
Zona Cafetera	-0.018 **	-0.347 ***	-0.058 **
	(0.008)	(0.053)	(0.026)
Coal Mines	0.033 ***	0.185 ***	-0.018
	(0.009)	(0.066)	(0.027)
Expansion of Ranching	-0.016	-0.412 ***	-0.181 ***
	0.013	0.076	0.037
Infrastructure/Market Access	0.003 *	-0.007	0.003
	0.002	0.012	0.005
Manuf. Employment	-1.946 ***	1.426	10.613 ***
	0.311	2.029	1.473
“Nivel de Vida”	0.024 ***	0.035 *	0.006
	0.003	0.020	0.009

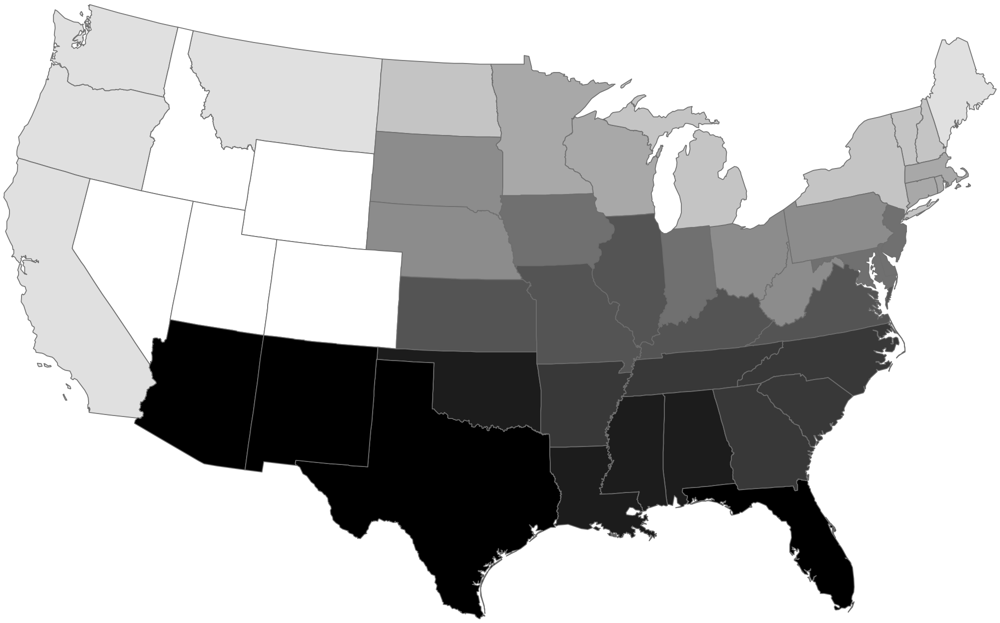
Notes: This table reports estimates of equation 4 using OLS. The units of observation are Colombian municipios. The dependent variables are as indicated in the column headings. Robust (Huber-White) standard errors in parentheses. Single asterisk denotes statistical significance at the 99% level of confidence; tilde at the 95% level. Reporting of constant term suppressed. Unexposed cohorts are those born before 1940 and fully exposed cohorts are those born after 1960. Cohorts are determined based on state of birth. The universe for the base sample consists of the native-born population between the ages of 25 and 55 (15–55 for literacy) in the 1973 and 1993 census microdata from the IPUMS.

Appendix Figure 1: Malaria Intensity by State in the United States

Panel A: Malaria Mortality as Fraction of Total, 1890

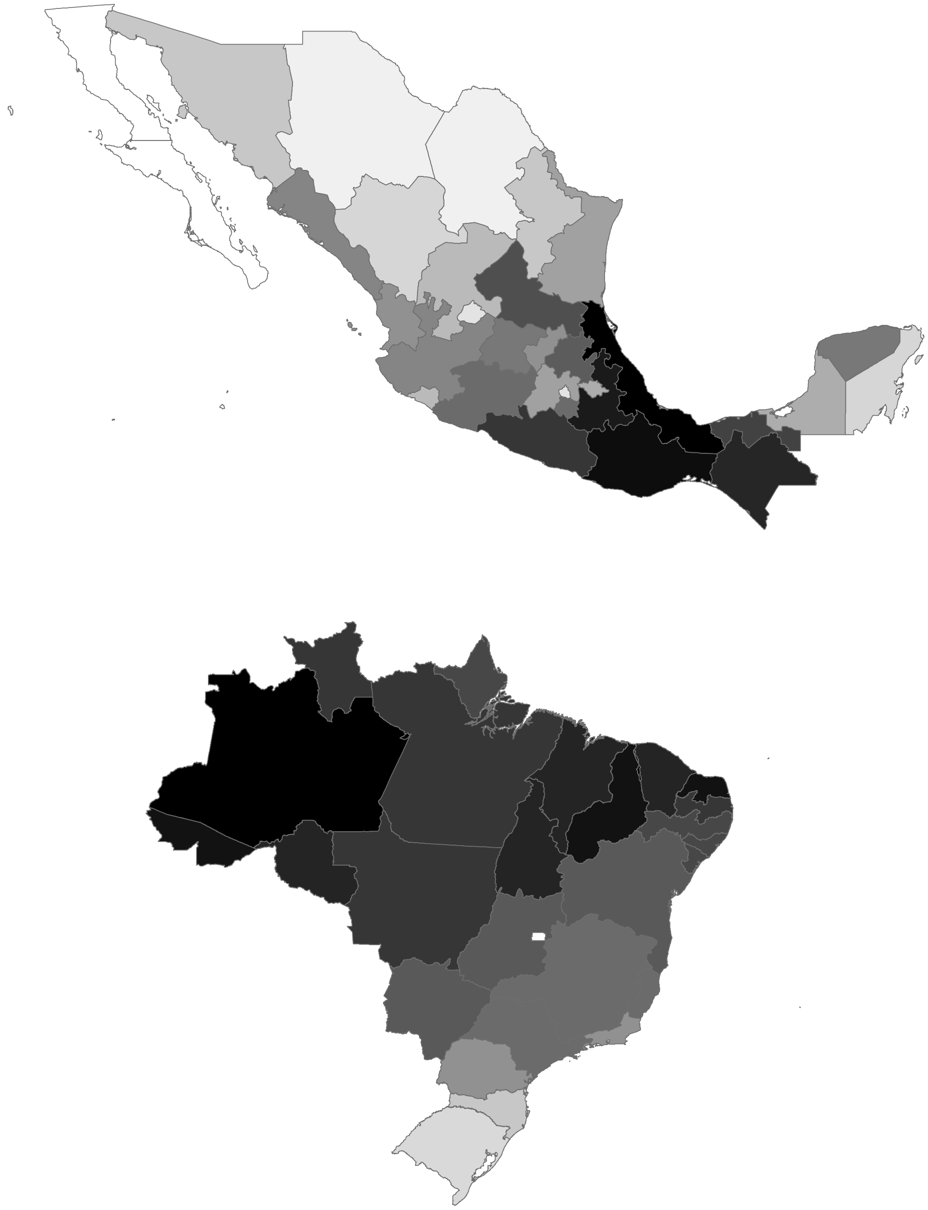


Panel B: Malaria Ecology (Mellinger)



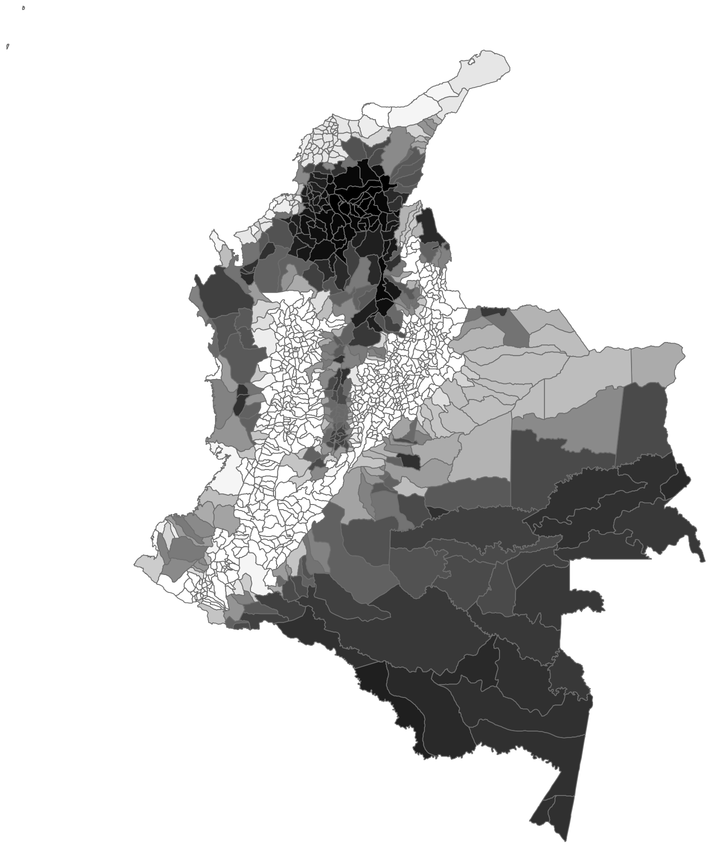
Notes: Displays a map of malaria intensity by states. Mortality data are drawn from the Census (1894). Ecology data are from Mellinger et al. (1999). Darker colors indicate more malaria.

Appendix Figure 2: Malaria Intensity by State in Mexico and Brazil



Notes: Displays a map of an index of malaria ecology as constructed by Mellinger and Sachs (2002). Darker colors indicate climatic and geographic conditions more conducive to the transmission of malaria.

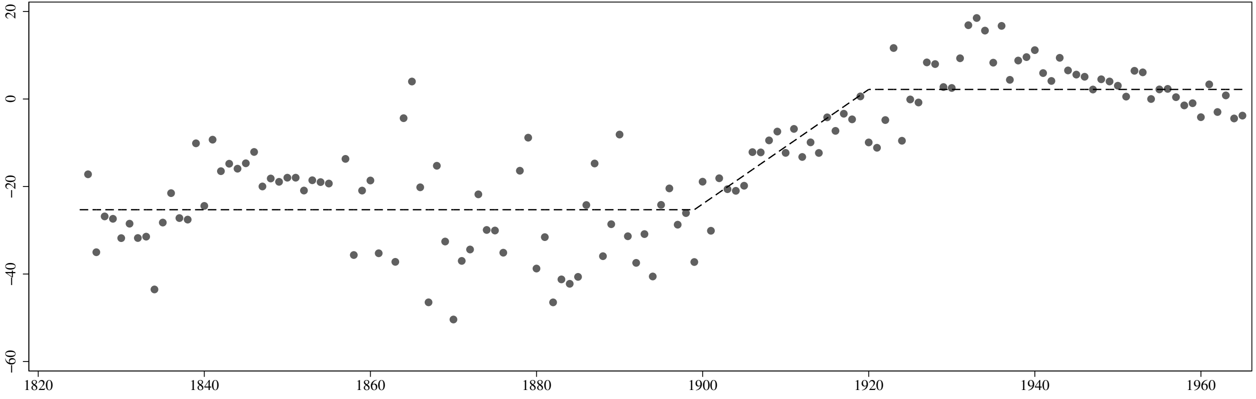
Appendix Figure 3: Malaria Intensity by Municipio in Colombia



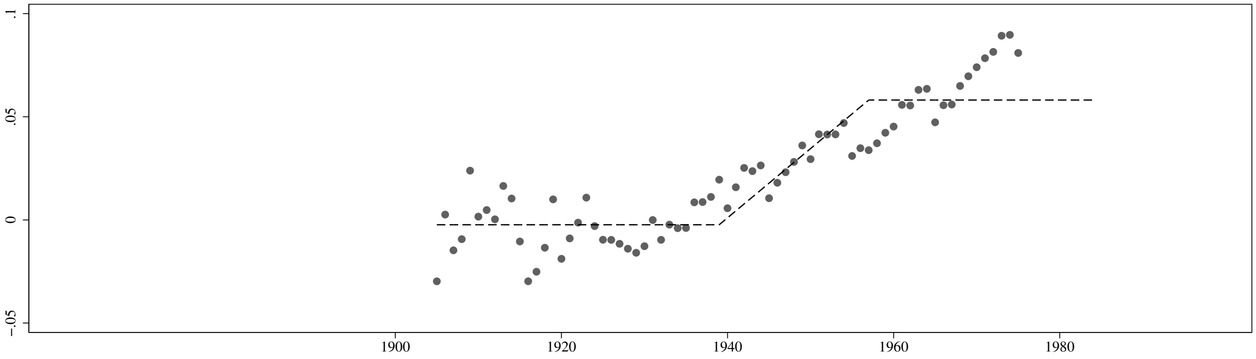
Notes: Displays a map of an index of malaria ecology as constructed by Mellinger and Sachs (2002). Darker colors indicate climatic and geographic conditions more conducive to the transmission of malaria.

Appendix Figure 4: Cohort-Specific Relationship between Malaria and Income Score

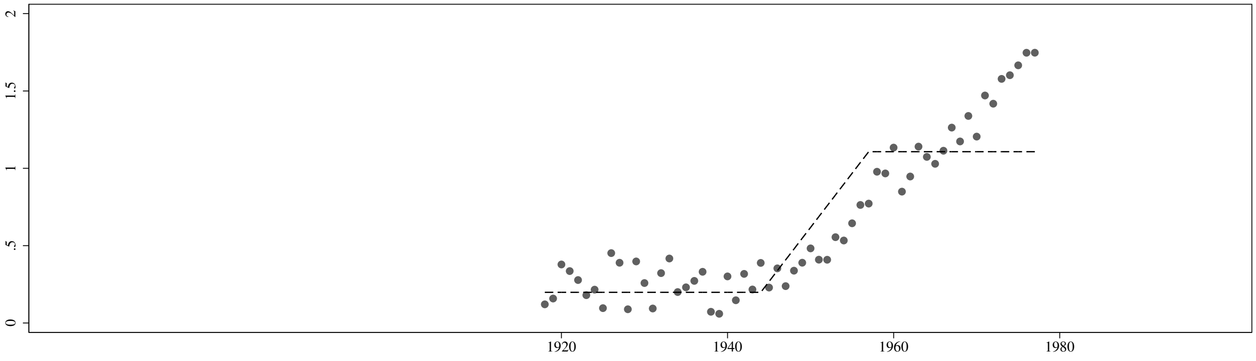
Panel A: United States



Panel B: Mexico and Brazil



Panel C: Colombia



Notes: Results for occupational proxies from Figures 6, 7, and 8 are reproduced here on a x scale that is normalized relative to the start-points of each area's malaria eradication campaign.