# Malaria Eradication in the Americas

## A Retrospective Analysis of Childhood Exposure

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# Introduction

- Public Health and Economic Outcomes
- Does disease cause underdevelopment in the tropics?
- Measure the effect of health environment!
  - Endogeneity
  - Targeted public-health interventions
  - This paper: efforts to combat malaria in the Americas
- Why childhood exposure?
- Childhood exposure to malaria suppresses income

# Why Study This Particular Disease?

1. Symptoms of the Disease
2. Still Prevalent in Much of the Tropical Belt
3. Circumstances that lead to the Campaign

# Two Key Antecedents to Eradication

1. Innovations to Knowledge
2. Innovations to Spending on Public Health

And the origins of both external to the affected regions.

# Program for the Talk

# Program for the Talk

# Geography or Human Influence?

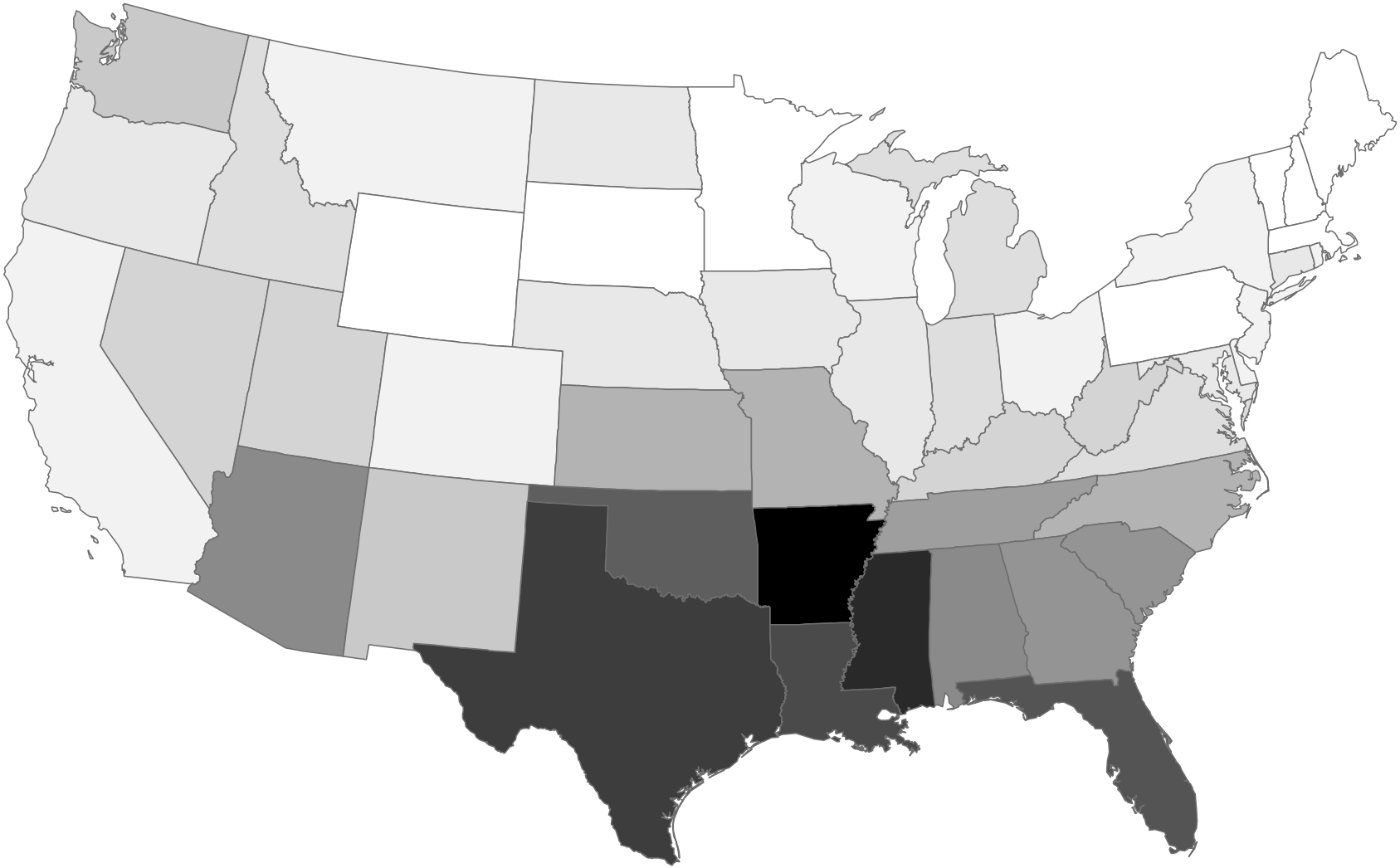
Geography:

1. Climatic Factors: Rainfall, Temperature.
2. Stagnant water, "low" altitude.
3. Local prevalence of vectors.

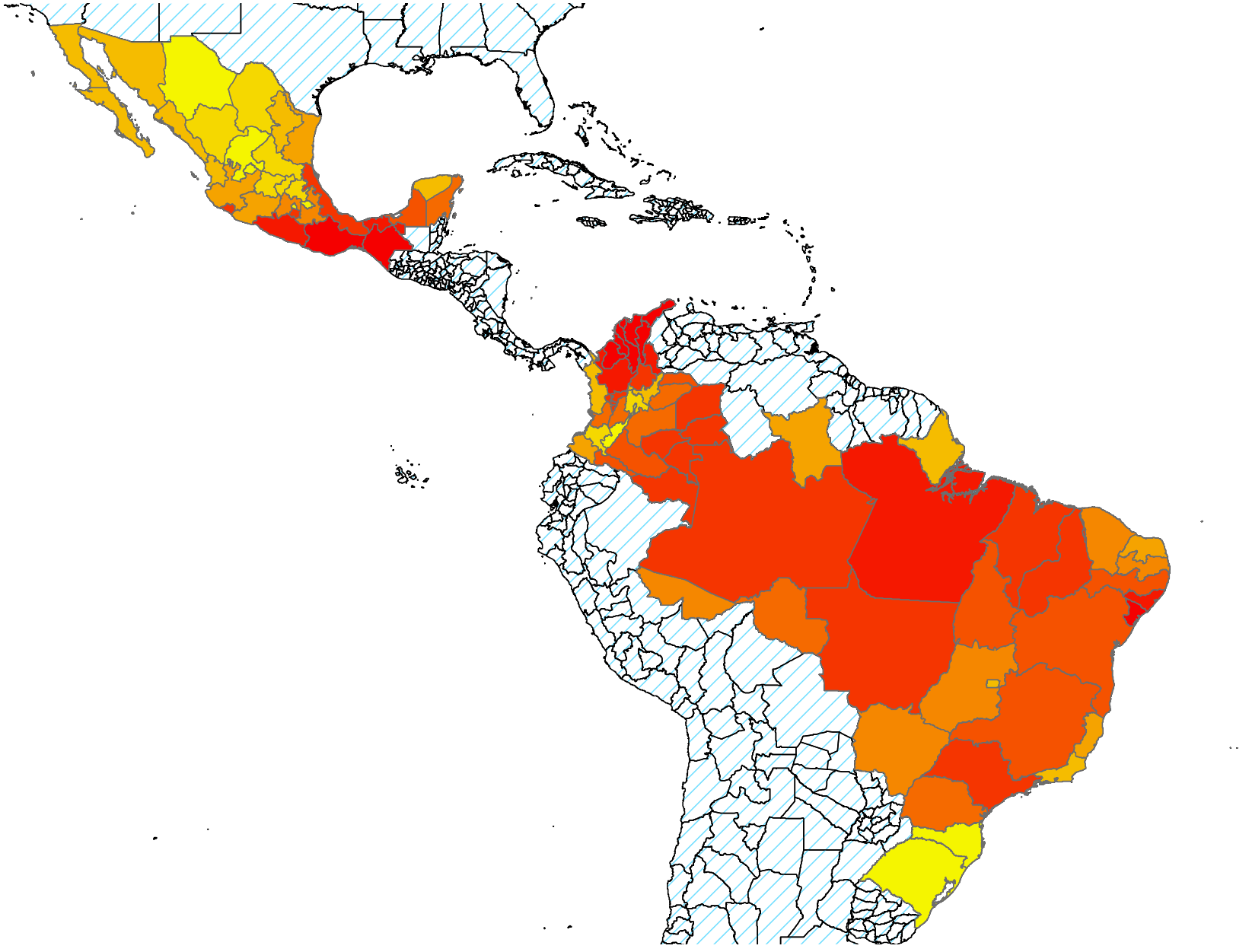
But institutional factors matter too!

1. Provision of public health
2. Unintended consequences of development (positive and negative)

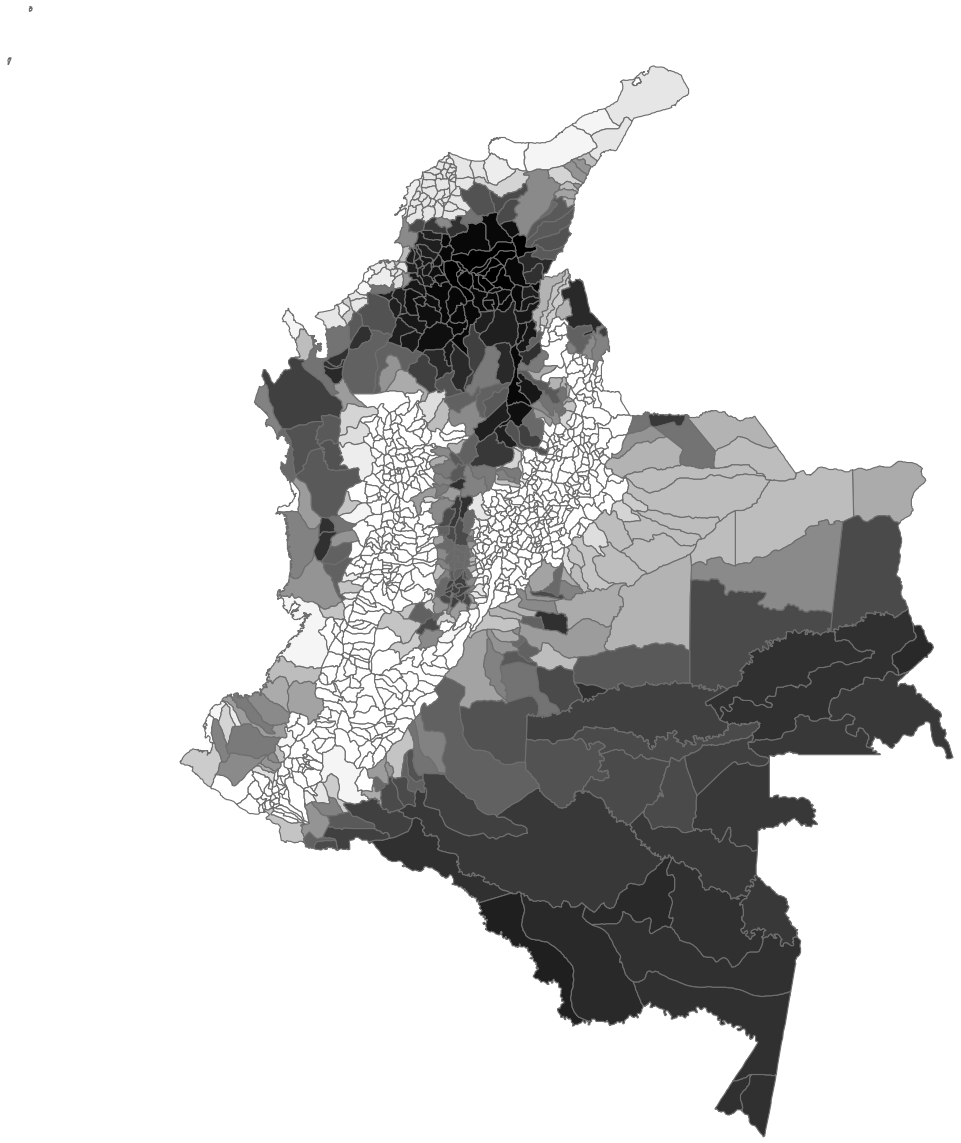
# Malaria: United States



# Malaria: LatAm



# Malaria Ecology: Colombia



# Program for the Talk

# Sir Ronald Ross

# The U.S. Takes an Interest

# The U.S. Takes an Interest

# "The First Mountain to be Removed"

# Benefits Accrue Back Home

This new knowledge was "repatriated" in the early 1920s.

↓

Large declines in malaria mortality followed.

# Mortality per 10K Population, Southern United States

# Peculiar Origins of the Campaign in LatAm

Mothballs

DDT

# Malaria Eradication in Latin America

1. Discovery of DDT
2. Application to WWII Effort
3. WHO Expands Program Worldwide
4. Colombia, Mexico, and Brazil implement programs in the 1950s

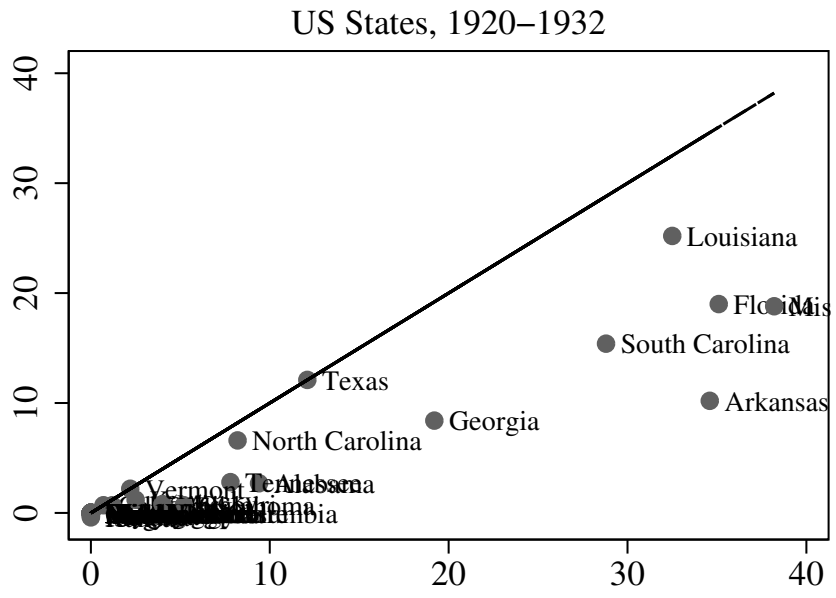
# Spraying of DDT

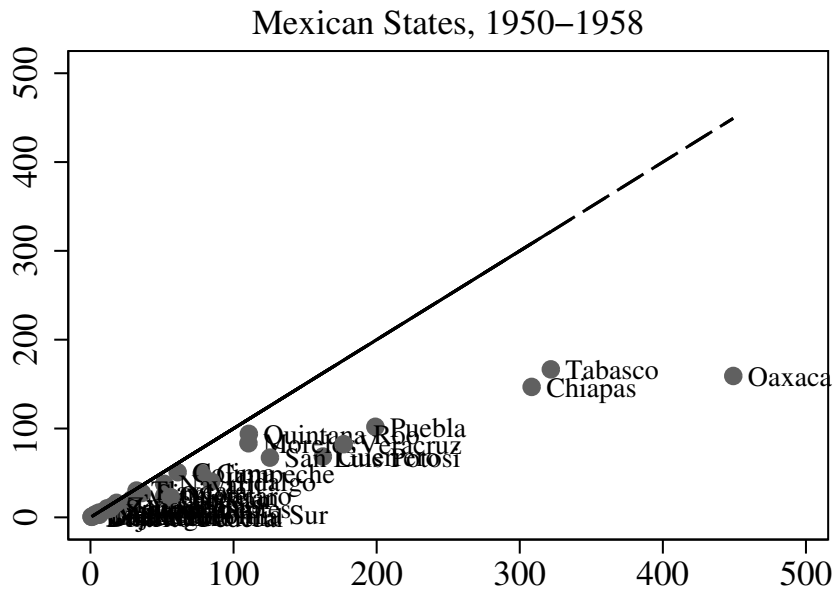
# Cases Notified per 1K Population, Colombia

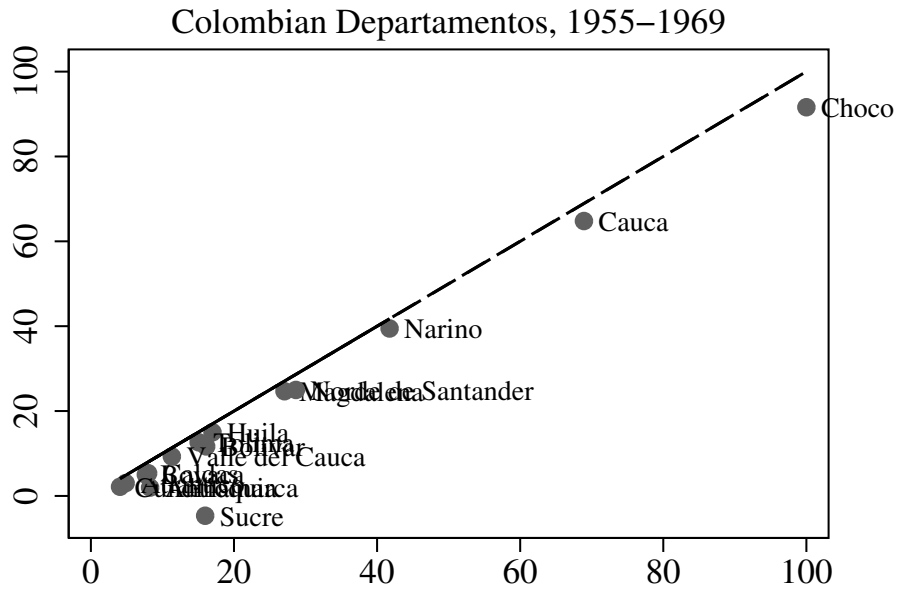
# Malaria Eradication

- Areas with Large Malaria Burdens Saw Large Declines in Morbidity

# Malarious Areas Saw Larger Declines



# Malaria Eradication

- Areas with Large Malaria Burdens Saw Large Declines in Morbidity.
- Are similar patterns evident for other outcomes?

# Program for the Talk

# Underlying Microdata

- Census samples (www.ipums.org)
  - $y =$
    1. Literacy
    2. Education
    3. Income (Brasil and Mexico)
    4. Occupational/Sectorial Indices of Income
  - Ages: [15,55] (Restricted to [25,55] for income and education.)
  - Native Males (whites for US)

# Construction of the Cohort-Level Data

- Start with the micro data.
- Average by area of birth and year of birth and census year. (3d panel)
- State of birth (United States, Brasil, Mexico)
- Municipio of birth (Colombia)

# Aggregate Regressors

- Controls
  - Published aggregates from censuses prior to campaigns
  - Anuarios Estadisticos
  - Maps (Banco de la República, Colombia)
  - Random stuff
- Malaria
  - Malaria Ecology
  - Cases notified (Colombia)
  - Mortality (US, Colombia, Mexico)
  - Blood samples (Colombia; Brasil) (spotty)

# Program for the Talk

# Research Design / Identifying Variation

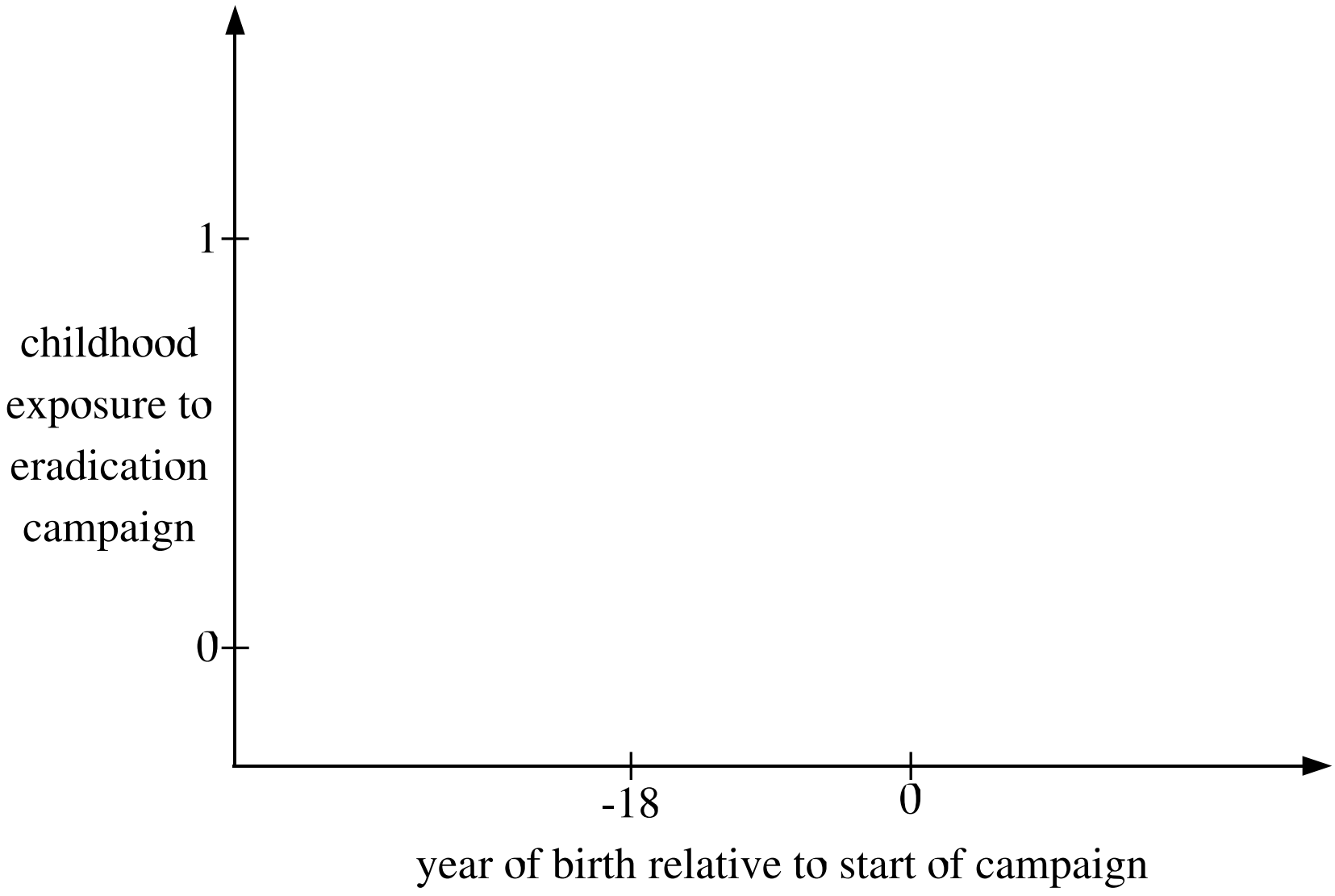
Part 1: The Effective Geography of Eradication

- Areas with large malaria burdens saw large declines in morbidity.
- Are similar patterns evident for other outcomes?

Part 2: Differential Exposure across Cohorts

- Childhood symptoms/infection worst
- Childhood as base of investments/development

# Childhood Exposure to Eradication Campaign



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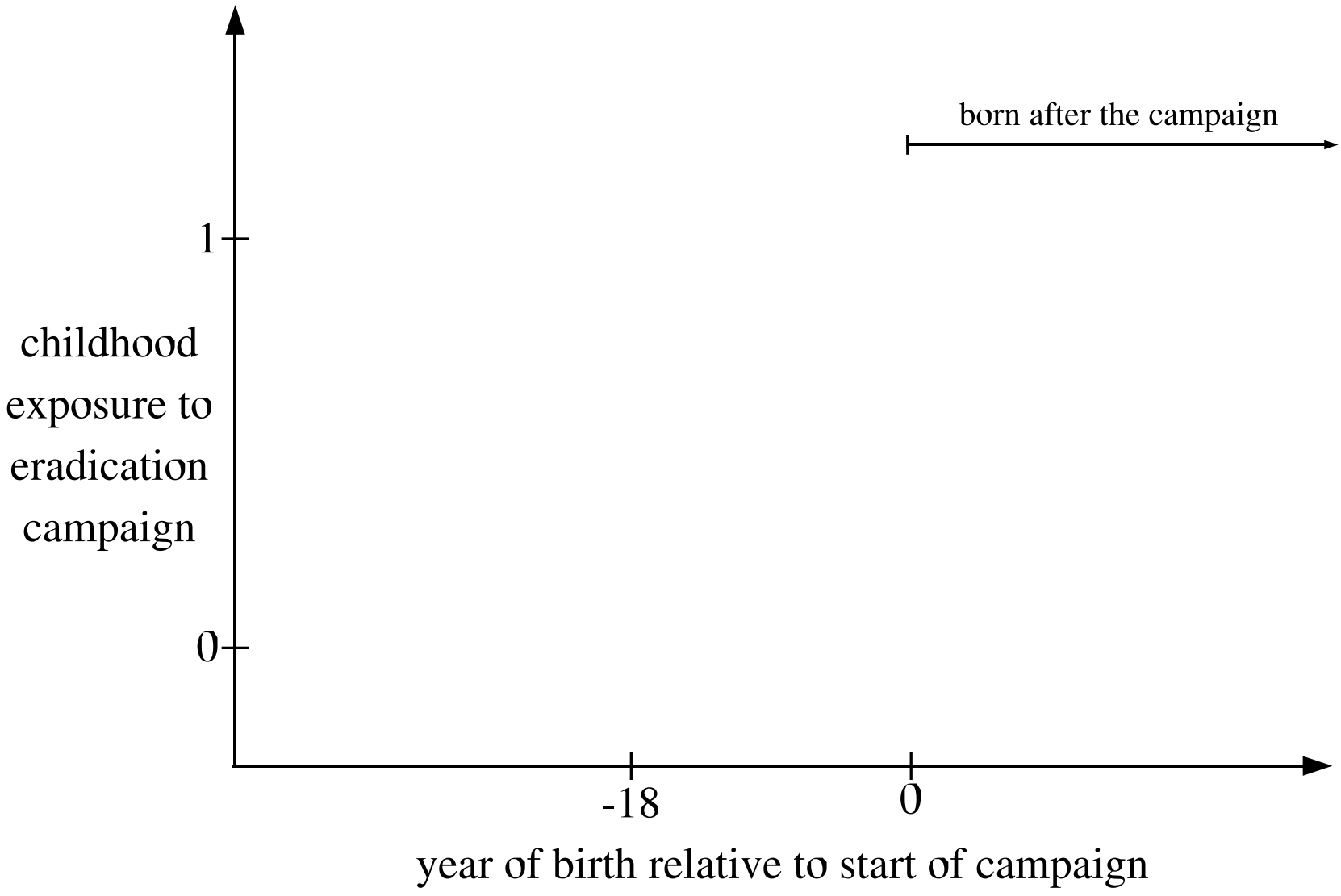

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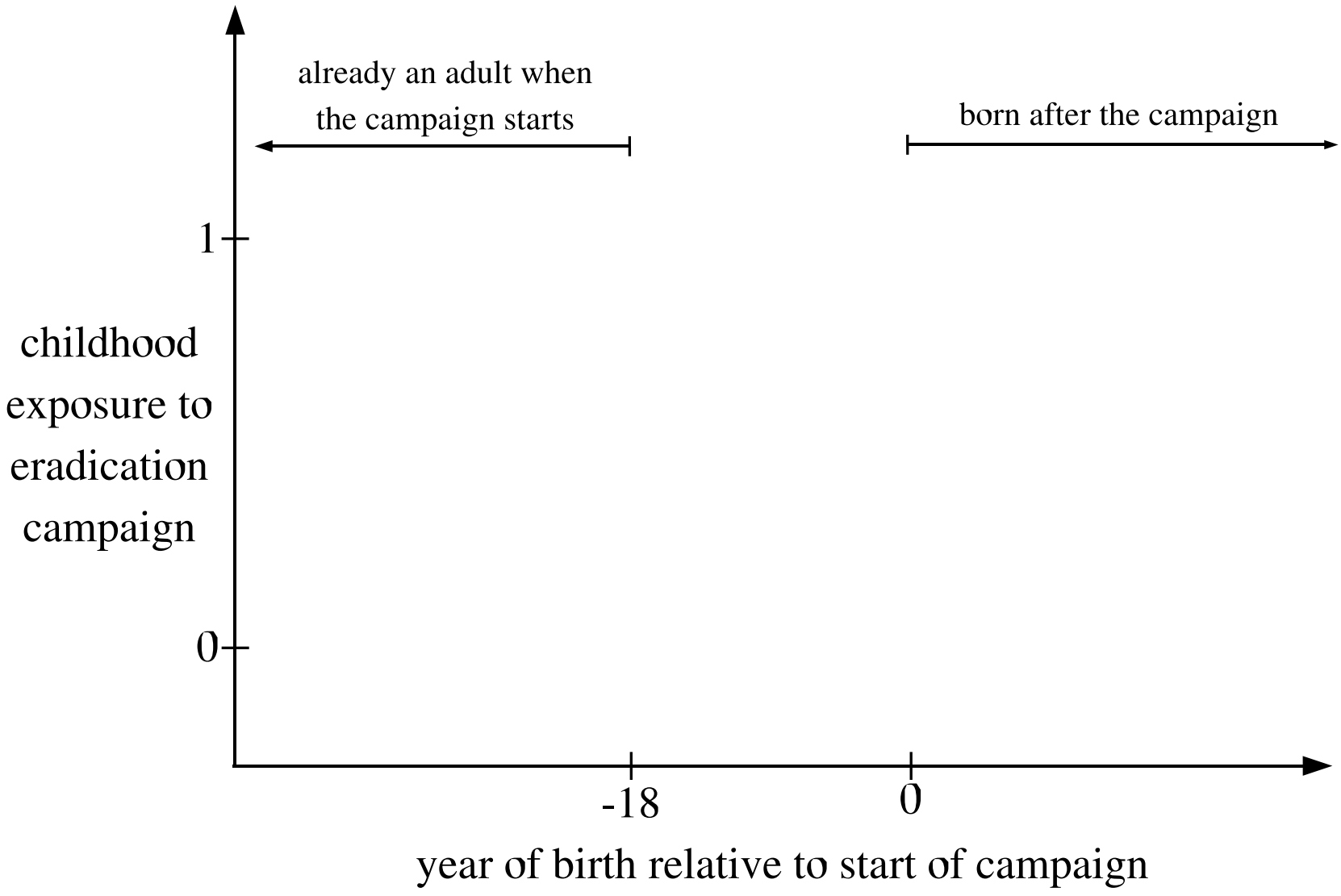

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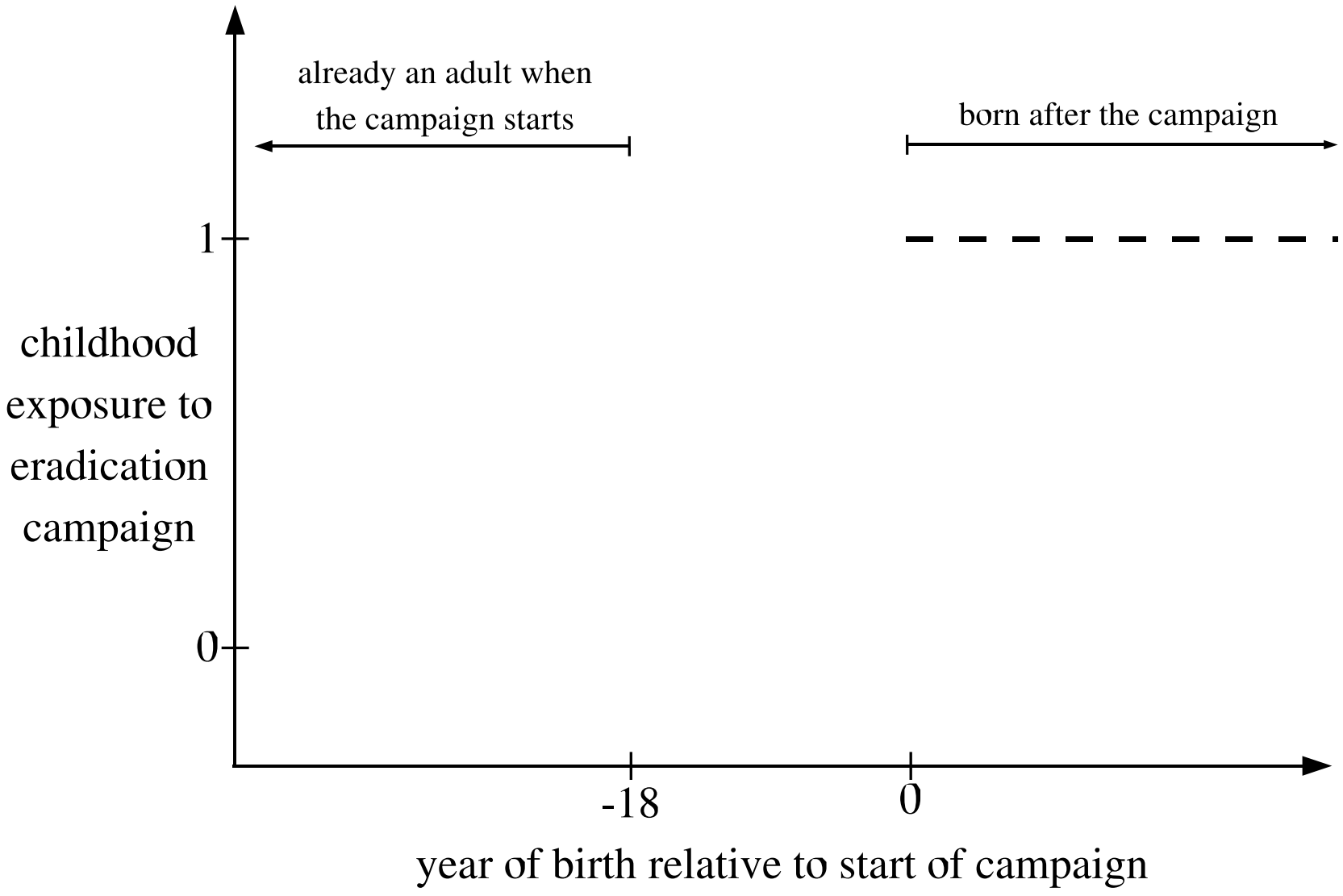

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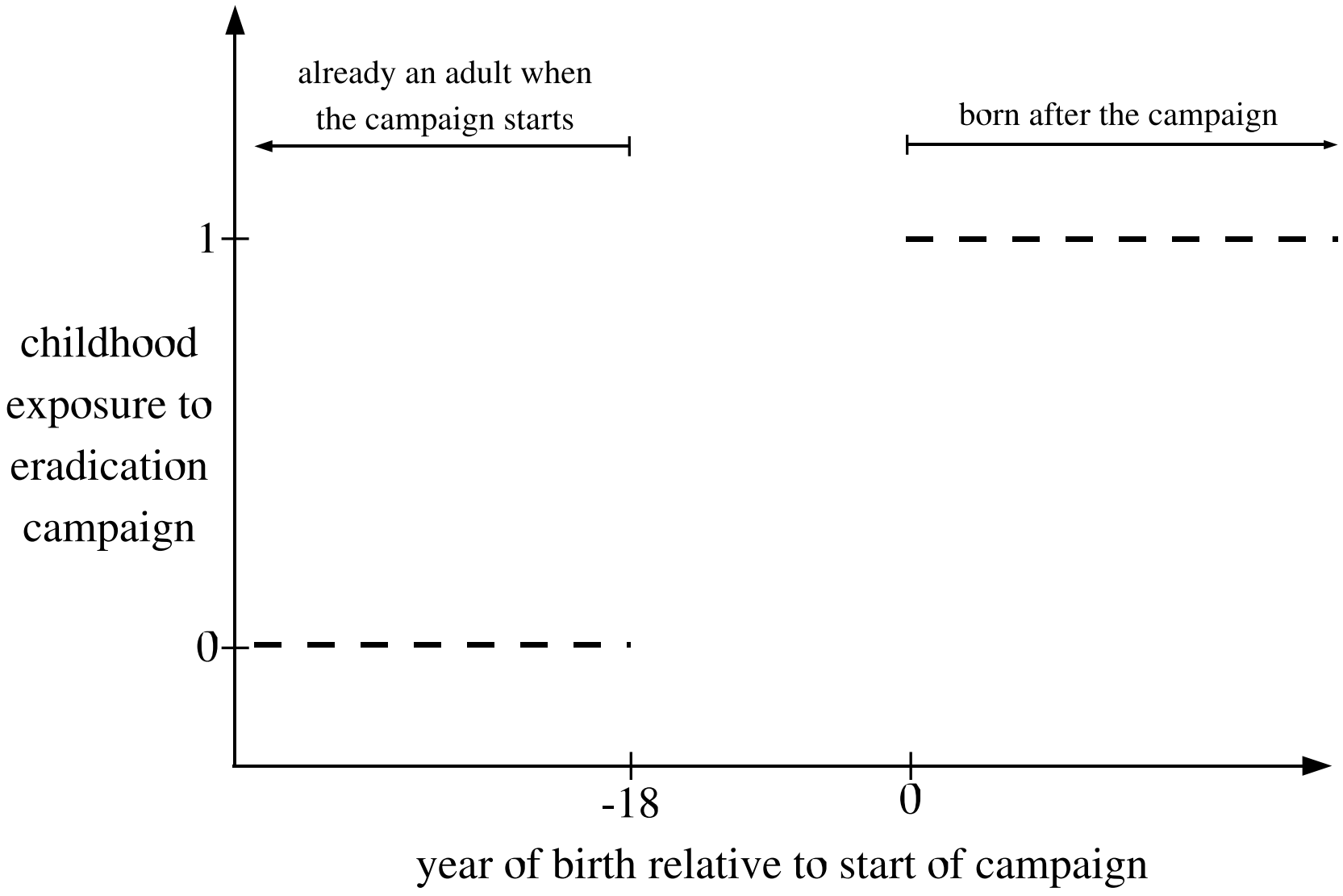

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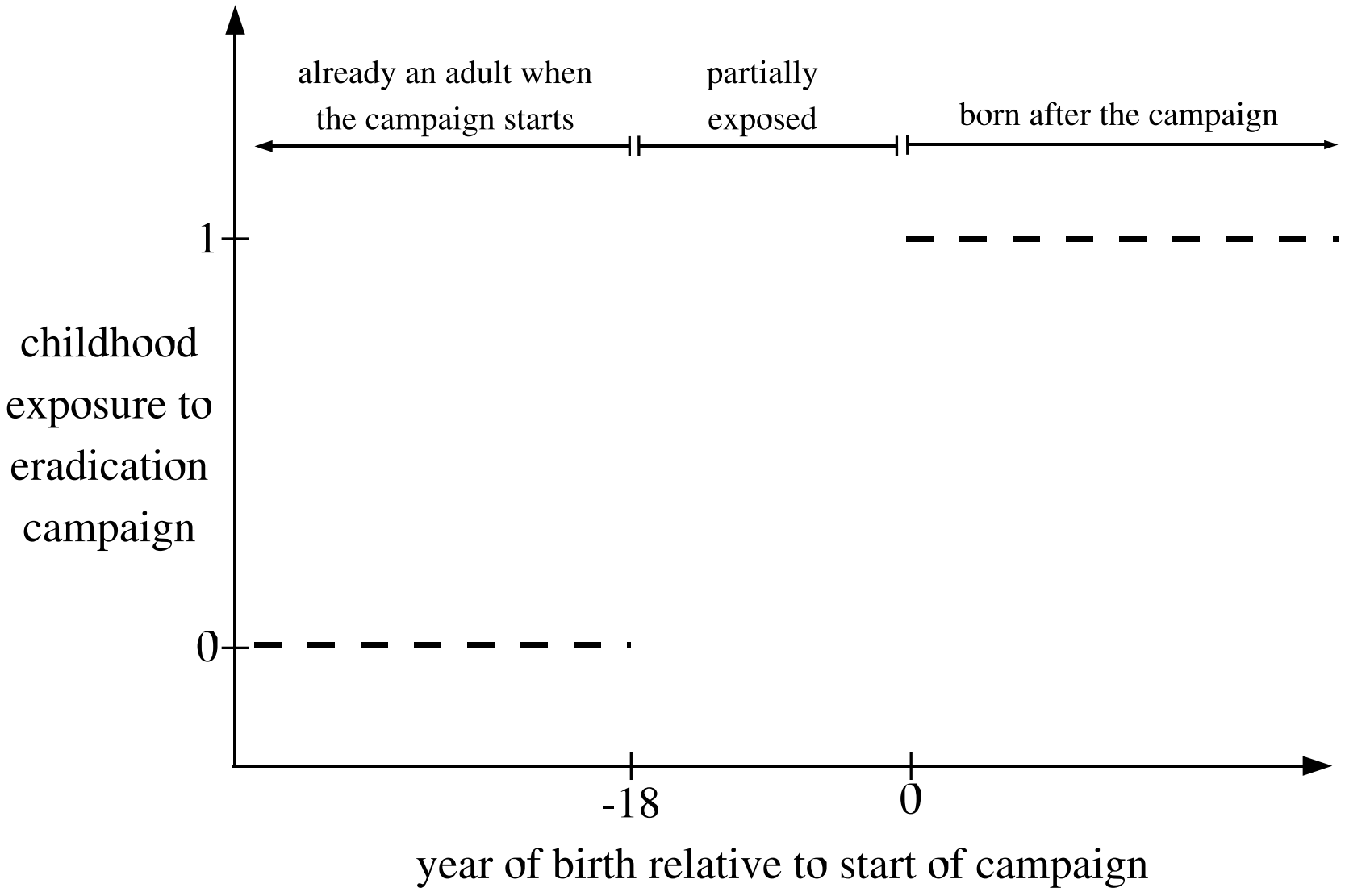

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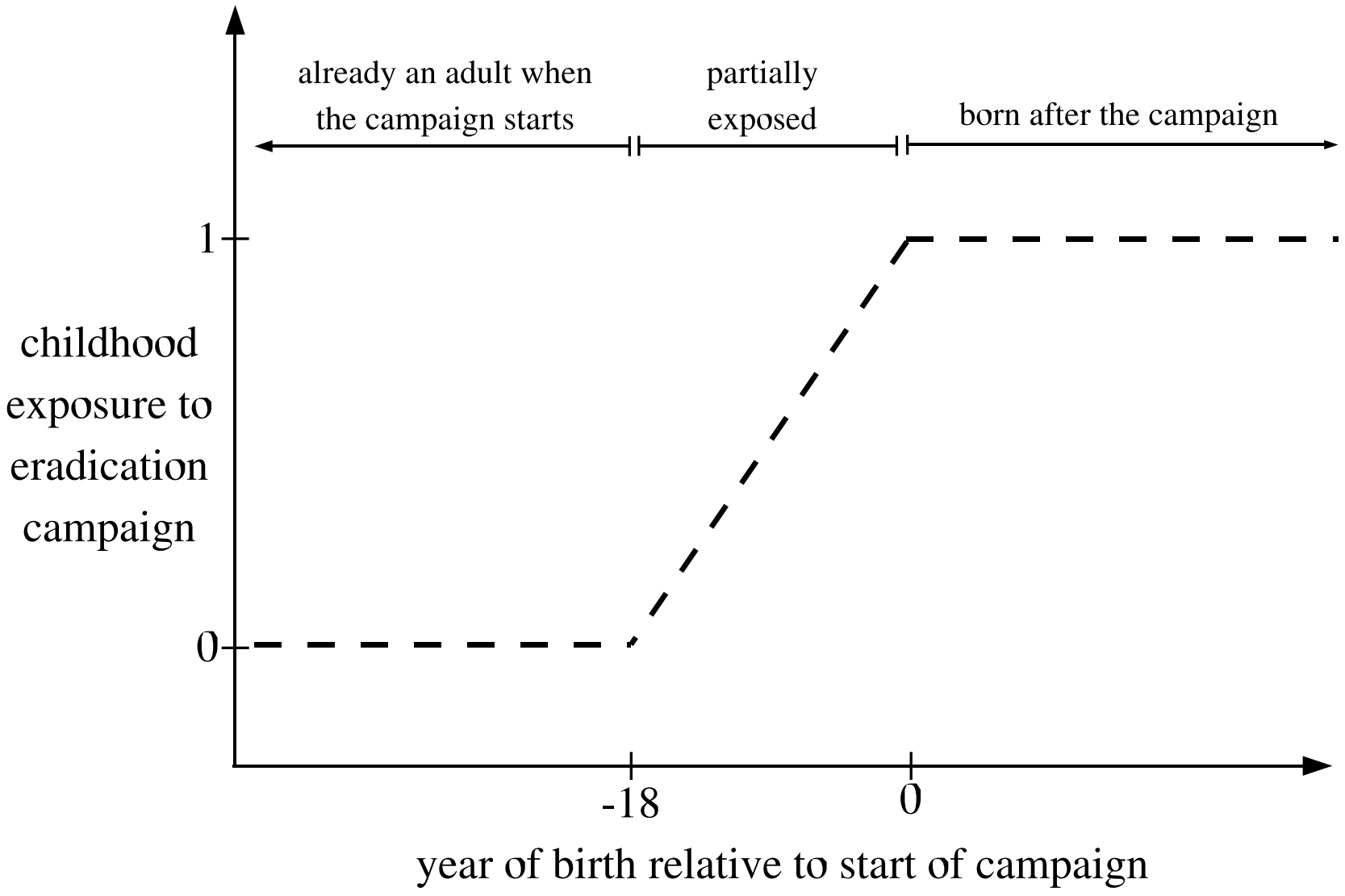

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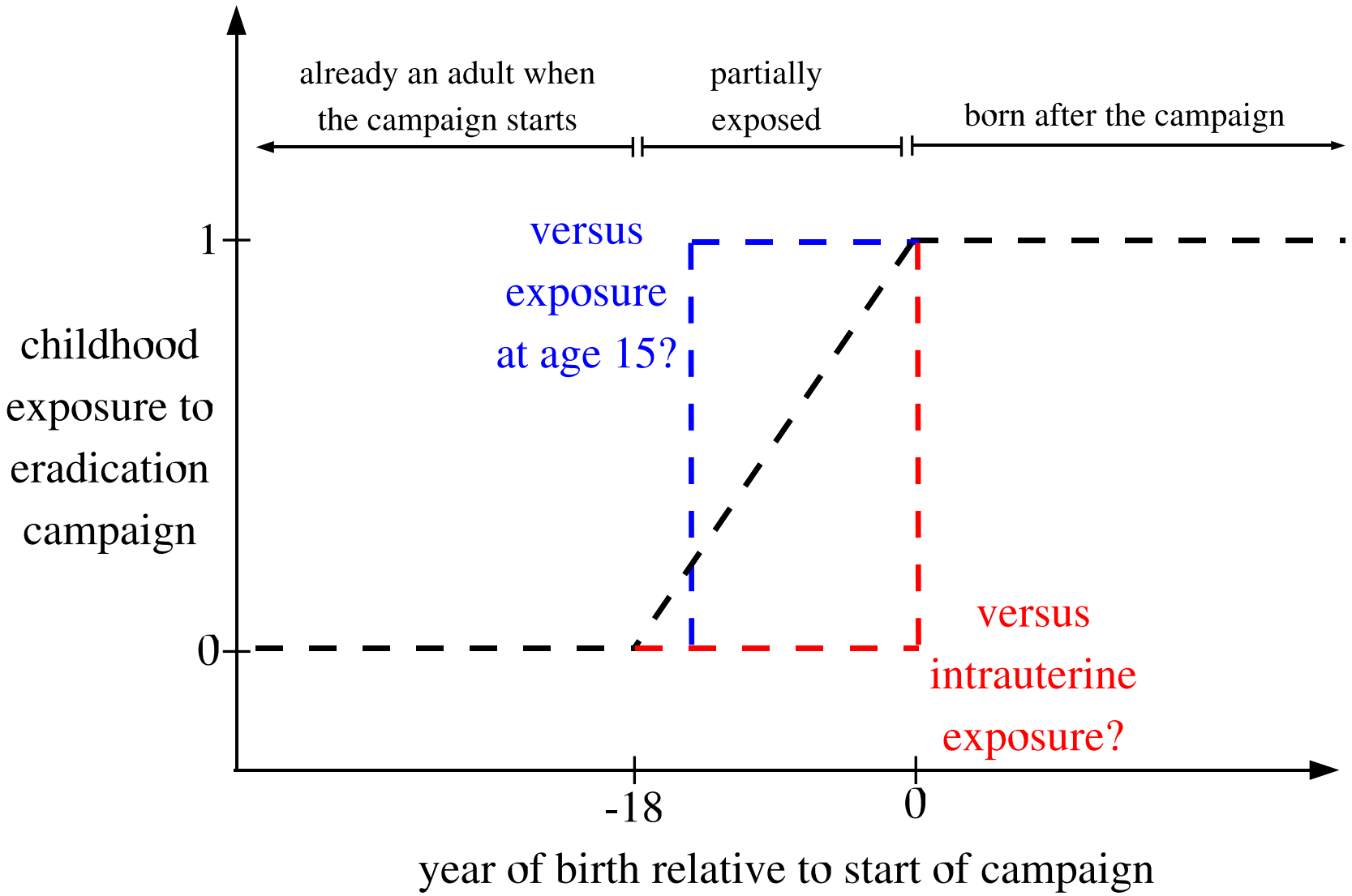

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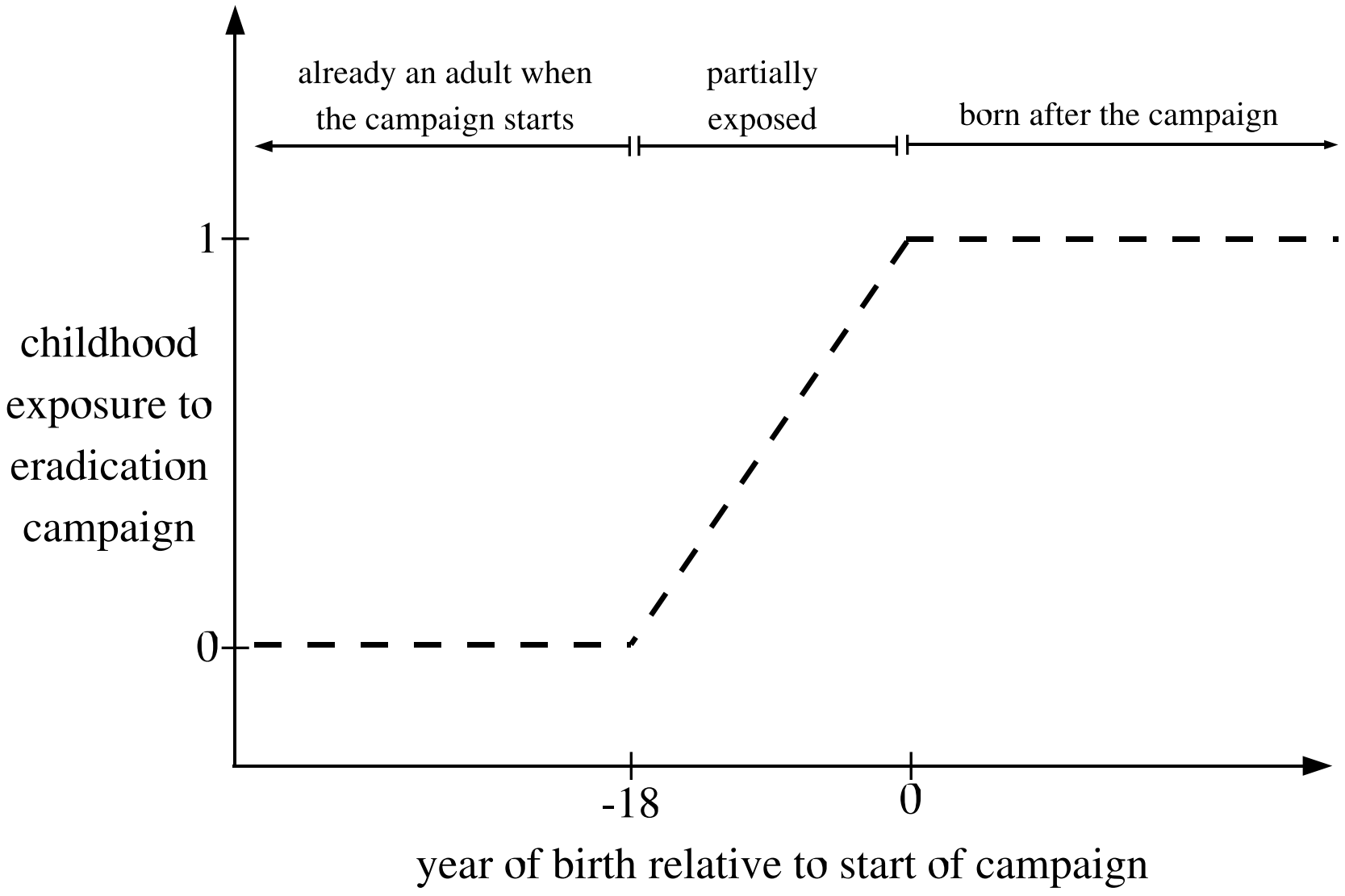

# When did the changes happen?

Cohort-by-cohort Estimates:

$$y_{it} = \alpha_t + \beta_t \mathrm{M}_i + X_i \Gamma_t + \epsilon_{it}$$

where $t$ is year of birth and $i$ is area of birth.

Plot the $\beta$.

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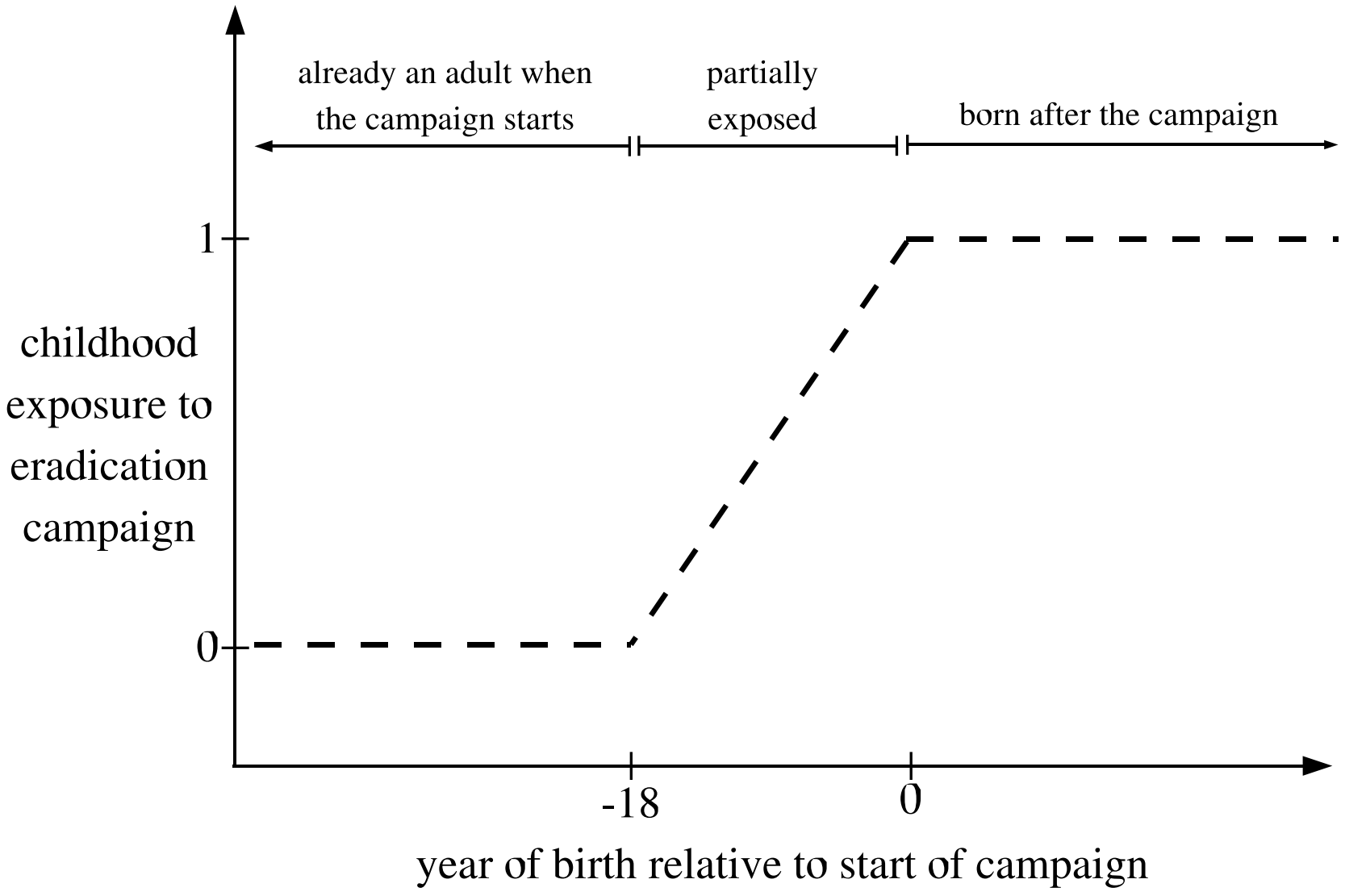
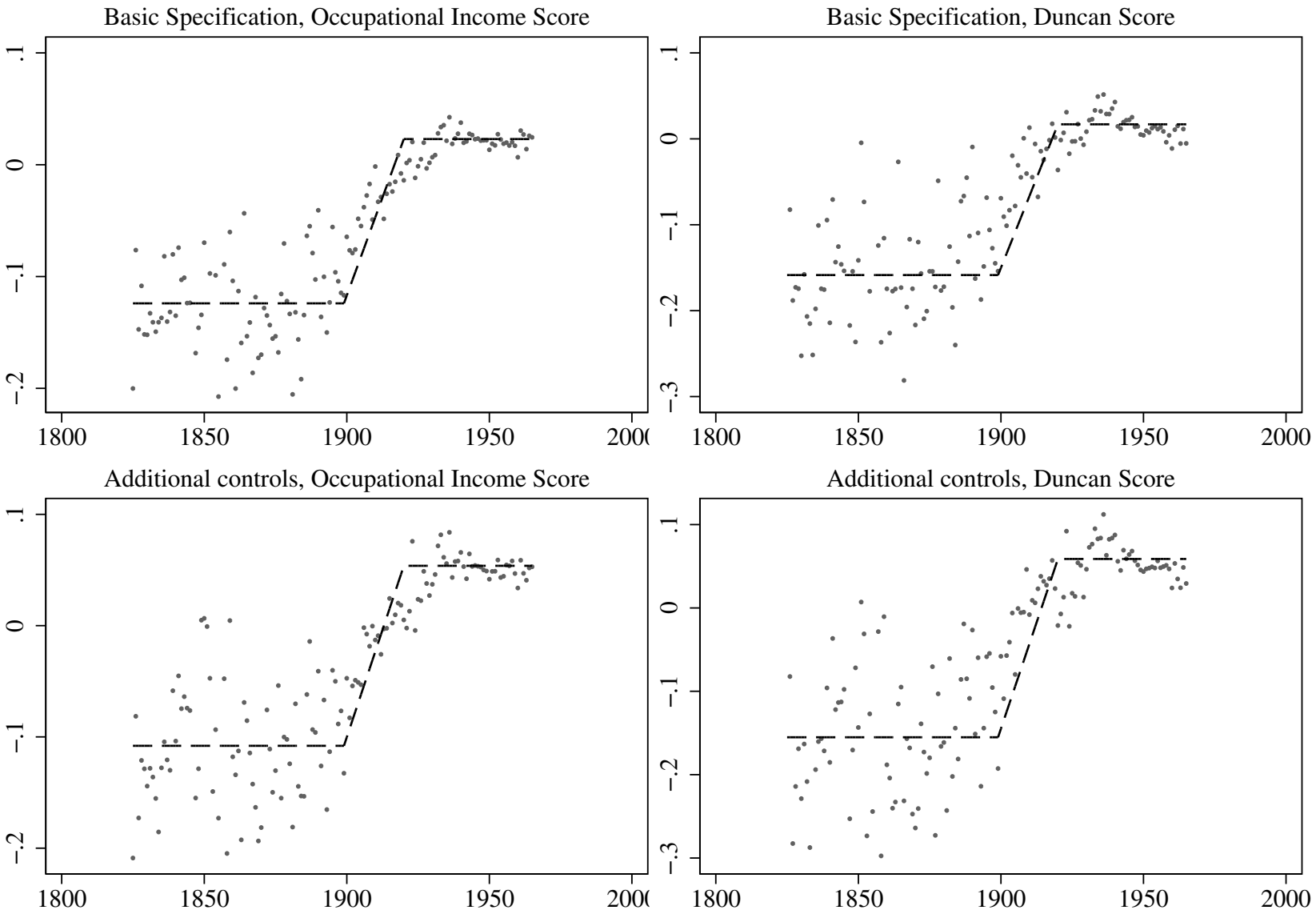
1. Do we observe a shift?
2. When does it happen?
3. Does it coincide with childhood exposure?

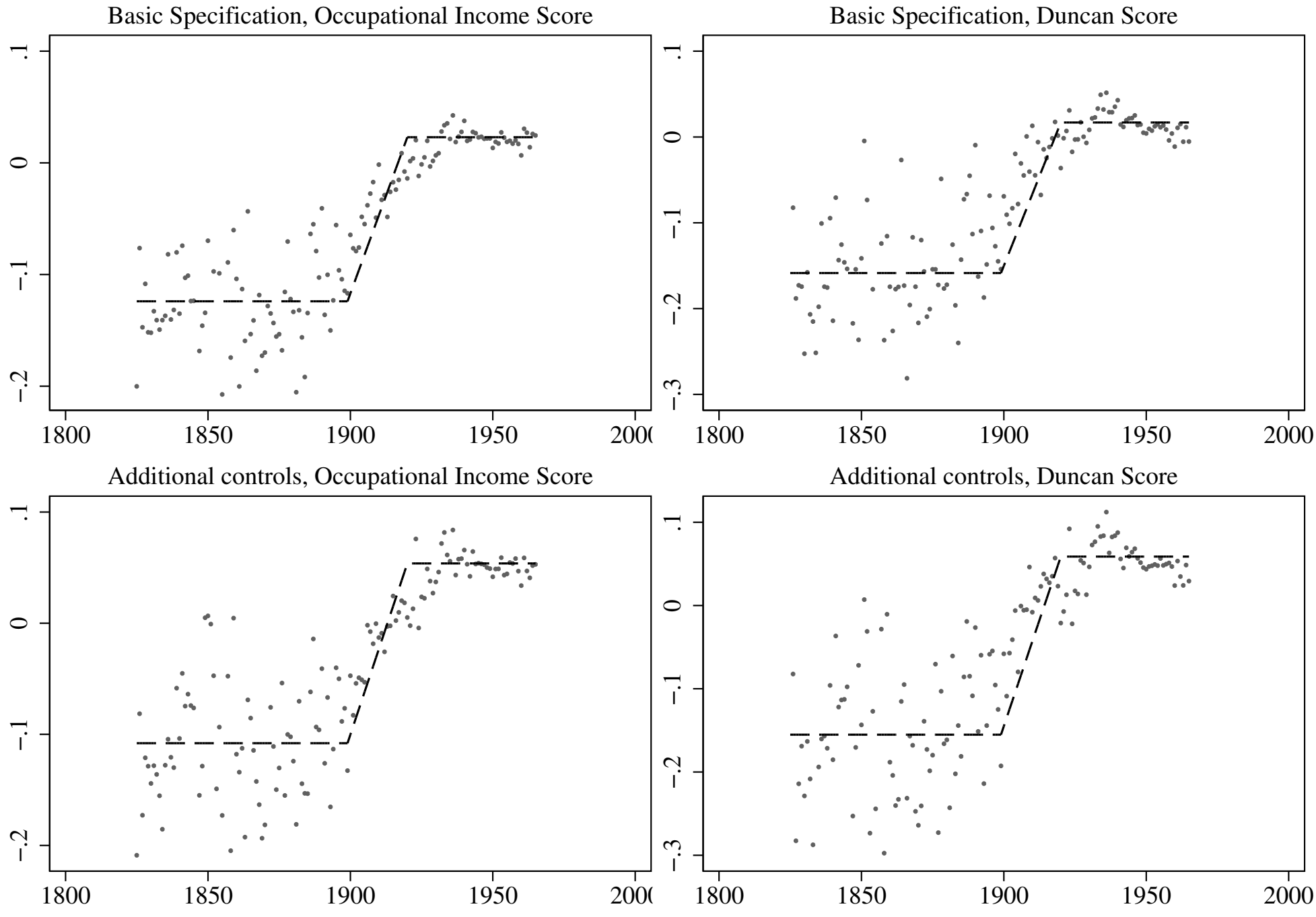
# Program for the Talk

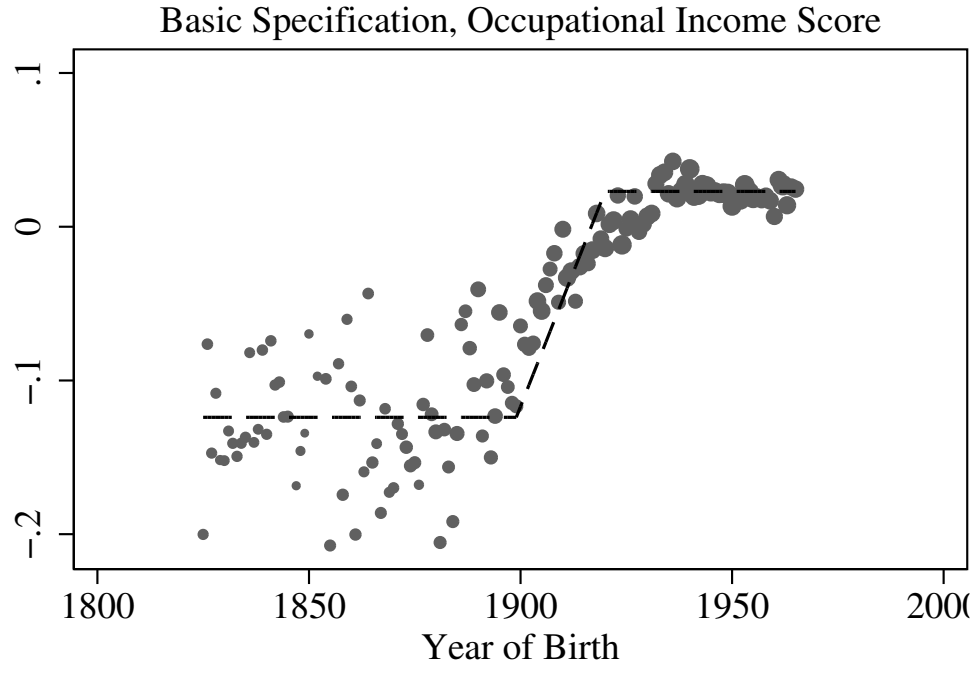
# Childhood Exposure to Eradication Campaign

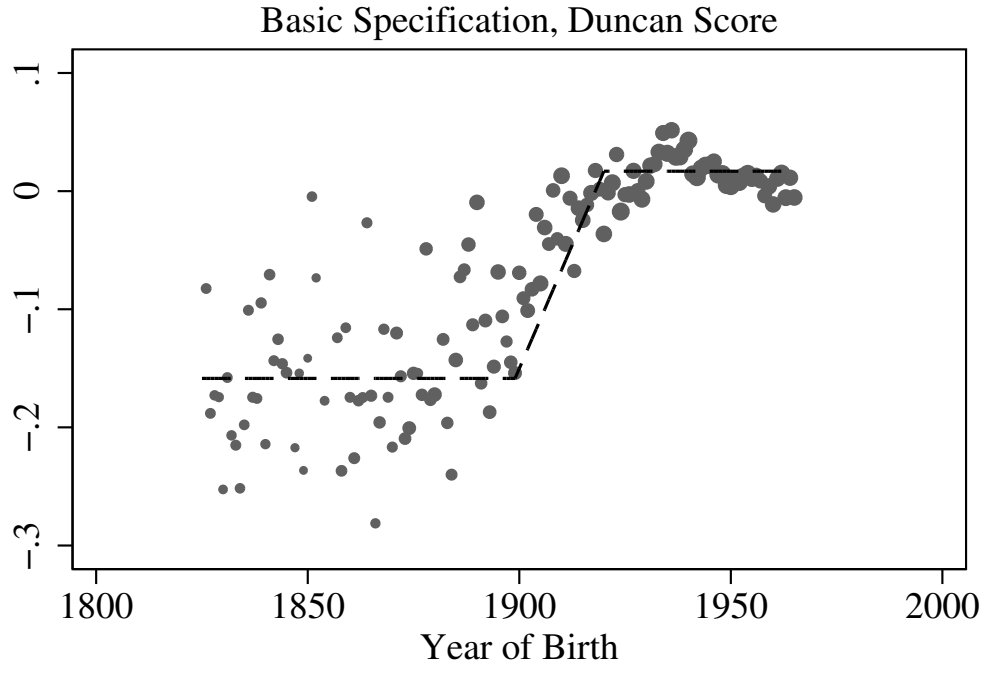


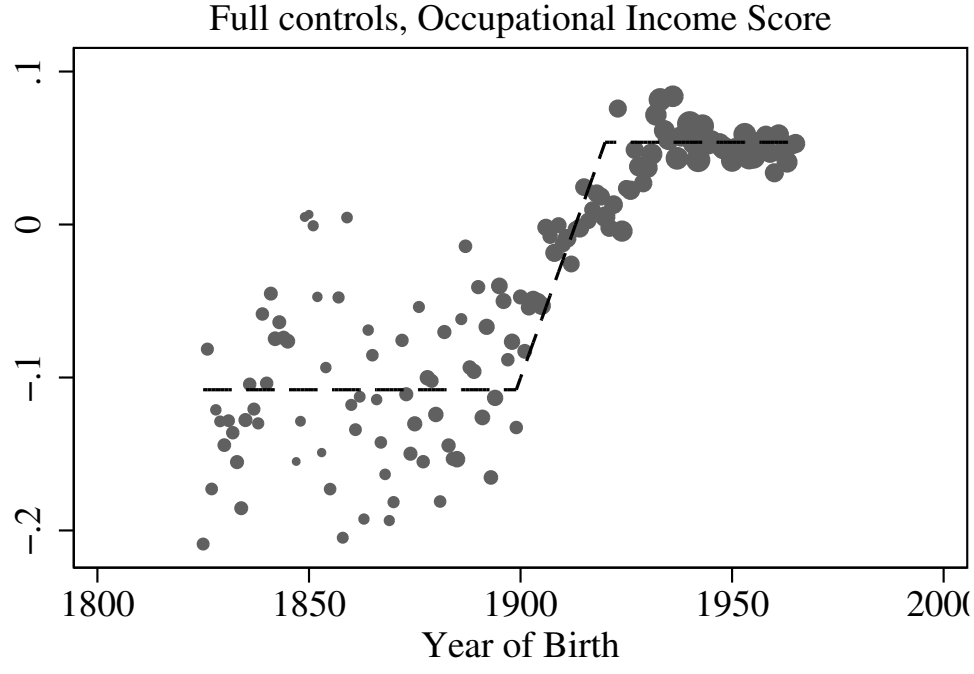
# Cohort-Specific Relationship: US States

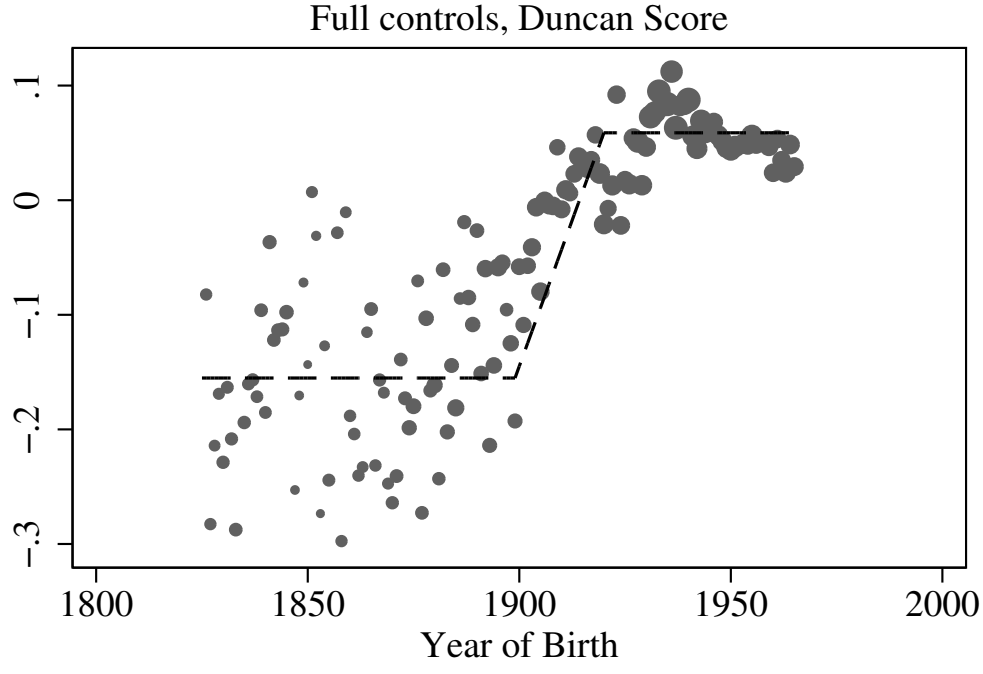



Basic Specification, Occupational Income Score
Basic Specification, Duncan Score
Additional controls, Occupational Income Score
Additional controls, Duncan Score
1800
1850
1900
1950
2000
.1
0
−.1
−.2
−.3


Basic Specification, Occupational Income Score
.1
0
−.1
−.2
1800
1850
1900
1950
200
Year of Birth


Basic Specification, Duncan Score
.1
0
−.1
−.2
−.3
1800
1850
1900
1950
2000
Year of Birth


Full controls, Occupational Income Score
.1
0
−.1
−.2
1800
1850
1900
1950
200
Year of Birth


Full controls, Duncan Score
.1
0
−.1
−.2
−.3
1800
1850
1900
1950
2000
Year of Birth

# United States: Variables (I)

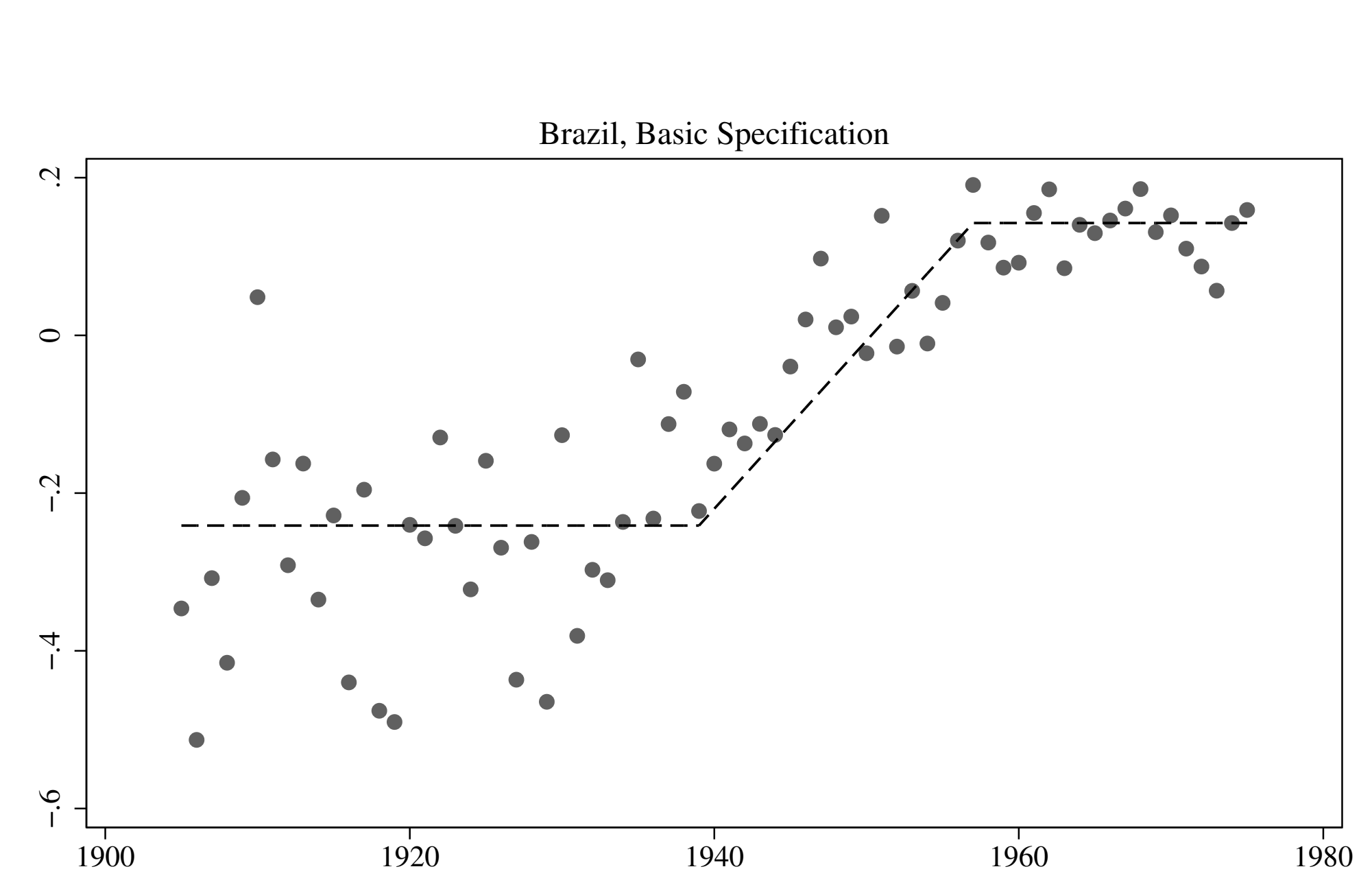
- Malaria mortality / total mortality, 1890.
- Region dummies
- Average unskilled wages, 1899 (Lebergott)
- Adult literacy rate (1910)
- Fraction of population living in urban areas (1910),
- unemployment rate (1930)
- 1902-32 logarithmic changes in school term length, pupil/teacher ratios.
- fertility rates (1910)

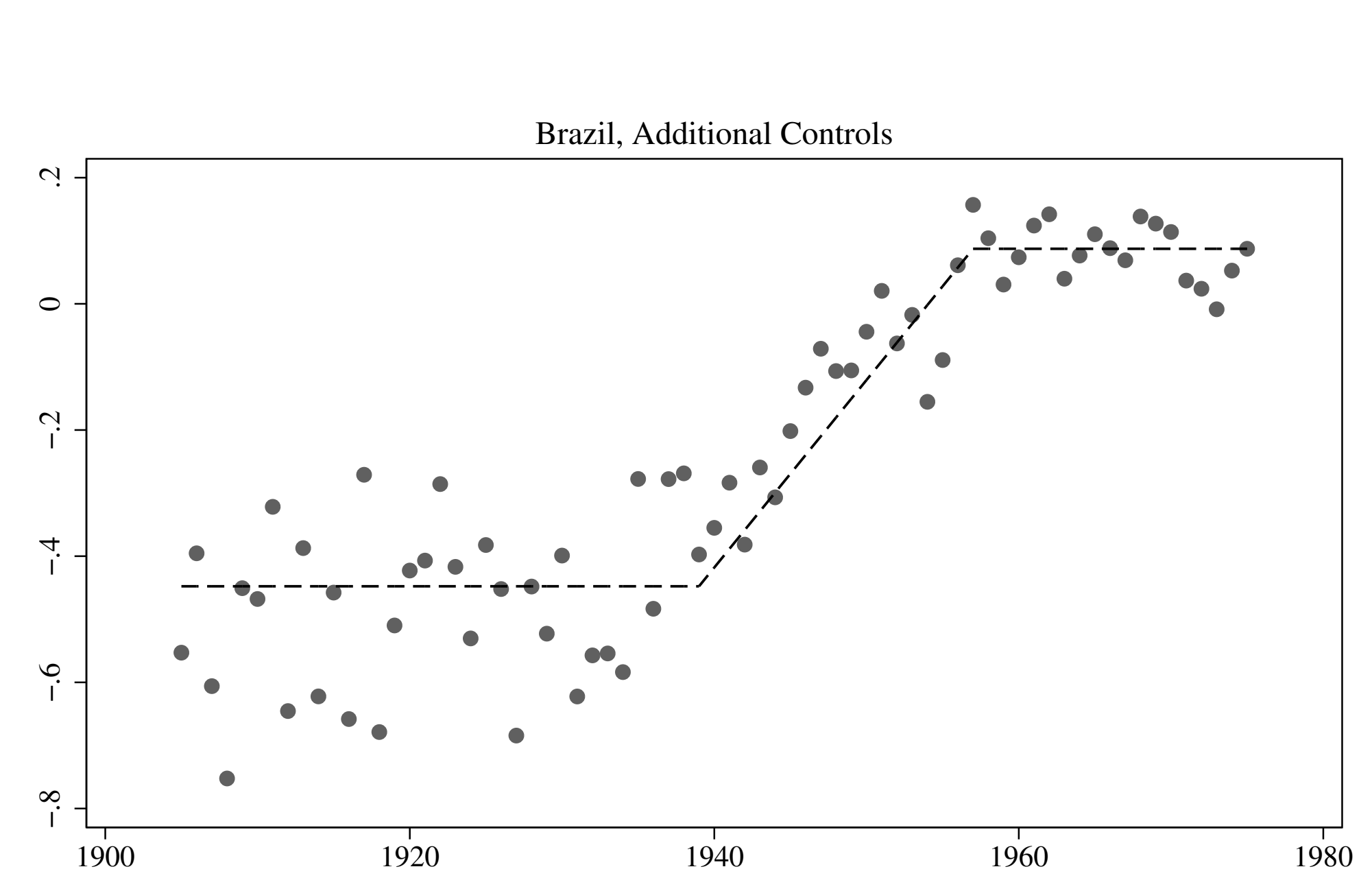
# United States: Variable (II: Health controls)

- fraction of deaths in 1890 caused by
  - scarlet fever
  - measles
  - whooping cough
  - diphtheria/croup
  - typhoid fever
  - diarrheal diseases
  - pneunomia
- Infant-mortality rate (1899)
- 1899-1932 change in infant mortality rates
- doctors per capita (1898)
- state public health spending per capita (1898)
- WWI recruits found "defective" at draft physical
- WWI recruits infected with hookworm

# Brazil: Variables

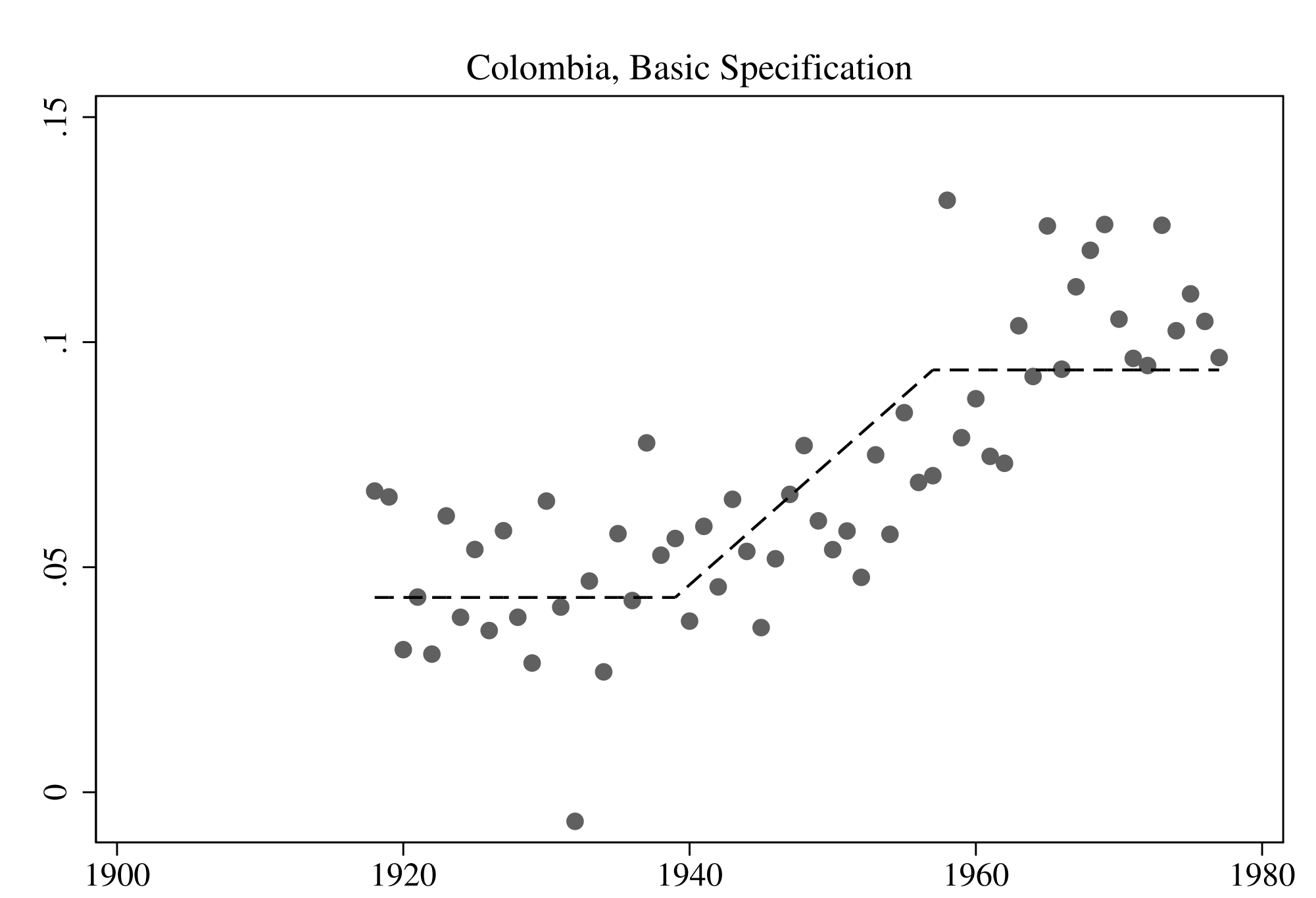
- Malaria ecology (Mellinger et al. 2005)
- Region dummies
- Population Density
- Infant mortality
- Log of Electricity Consumption
- Fraction of pop economically active
- Share of labor force in...
  - Agriculture
  - Extractive Industries
  - Manufacturing
  - Transportation
  - Services


Brazil, Basic Specification
.2
0
−.2
−.4
−.6
1900
1920
1940
1960
1980


Brazil, Additional Controls
.2
0
−.2
−.4
−.6
−.8
1900
1920
1940
1960
1980

# Colombia: Variables

- Malaria ecology (Poveda et al. 2000)
- Region dummies
- "La Violencia" before 1955, 1955 and after
- High Concentration "Minifundista"
- Coffee-growing Region
- Coal Mining Region
- Expansion of Ranching, 1960+
- Infrastructure/Market Access
- Share of labor force in manufacturing
- General level of development ("Nivel de Vida")


Colombia, Basic Specification
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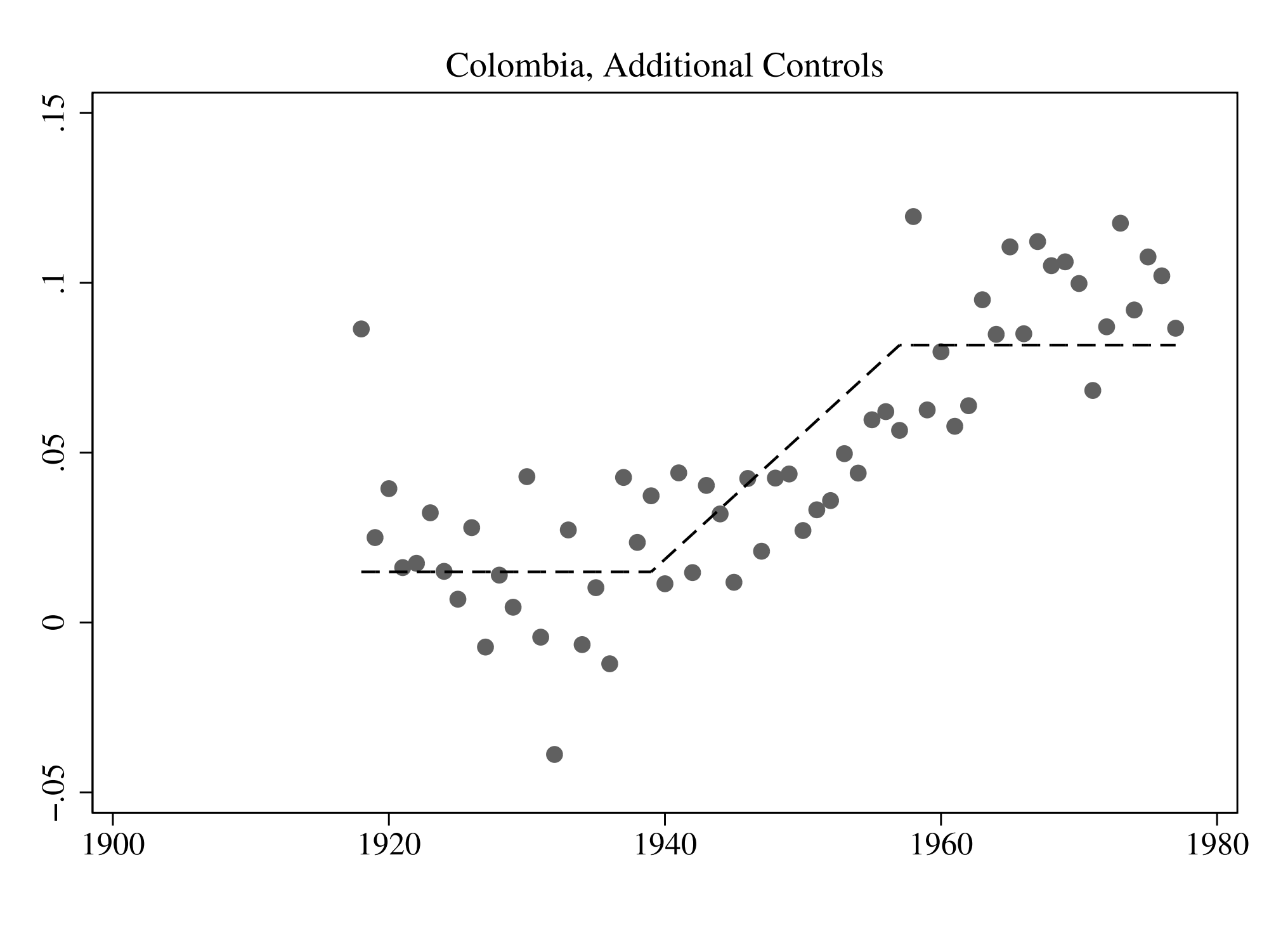
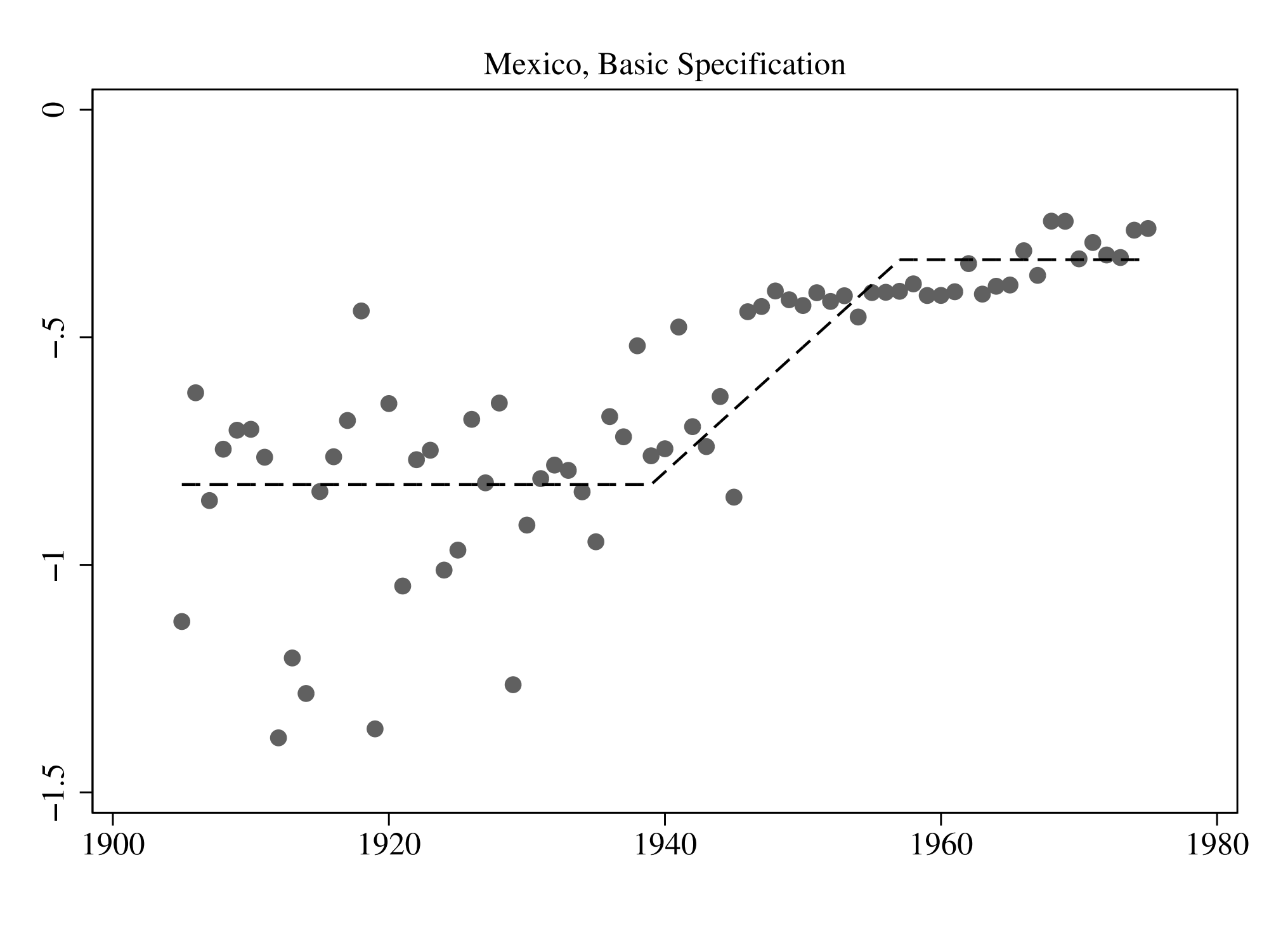
1900
1920
1940
1960
1980


Colombia, Additional Controls
.15
.1
.05
0
−.05
1900
1920
1940
1960
1980

# Mexico

- Malaria mortality per 1000 population, 1949-1953
- Region dummies
- Population Density
- Infant mortality
- Log of Electricity Consumption
- Fraction of pop economically active
- Share of labor force in...
  - Agriculture
  - Extractive Industries
  - Manufacturing
  - Transportation
  - Services
- Household income GINIs


Mexico, Basic Specification
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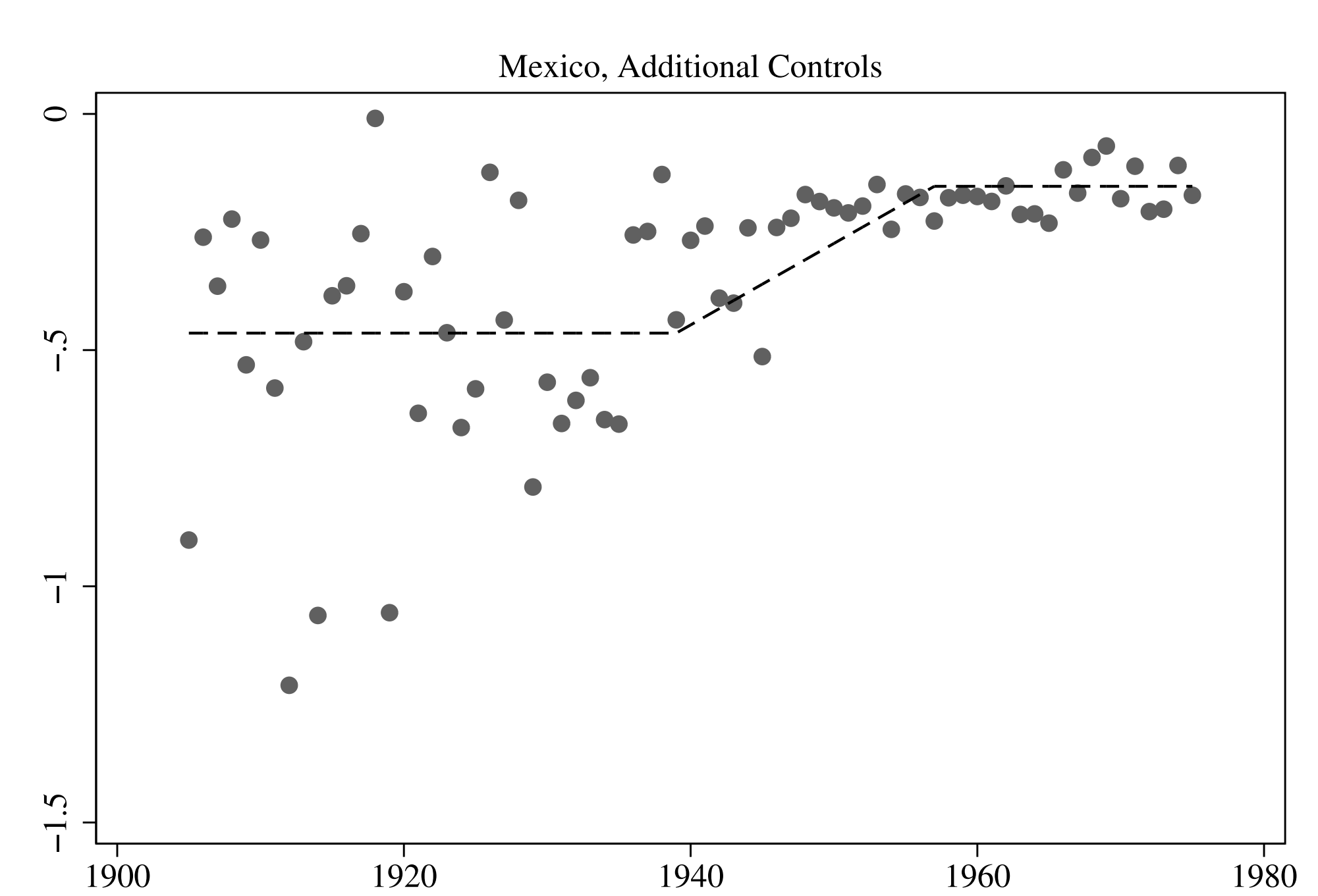
−1
−1.5
1900
1920
1940
1960
1980


Mexico, Additional Controls
0
−.5
−1
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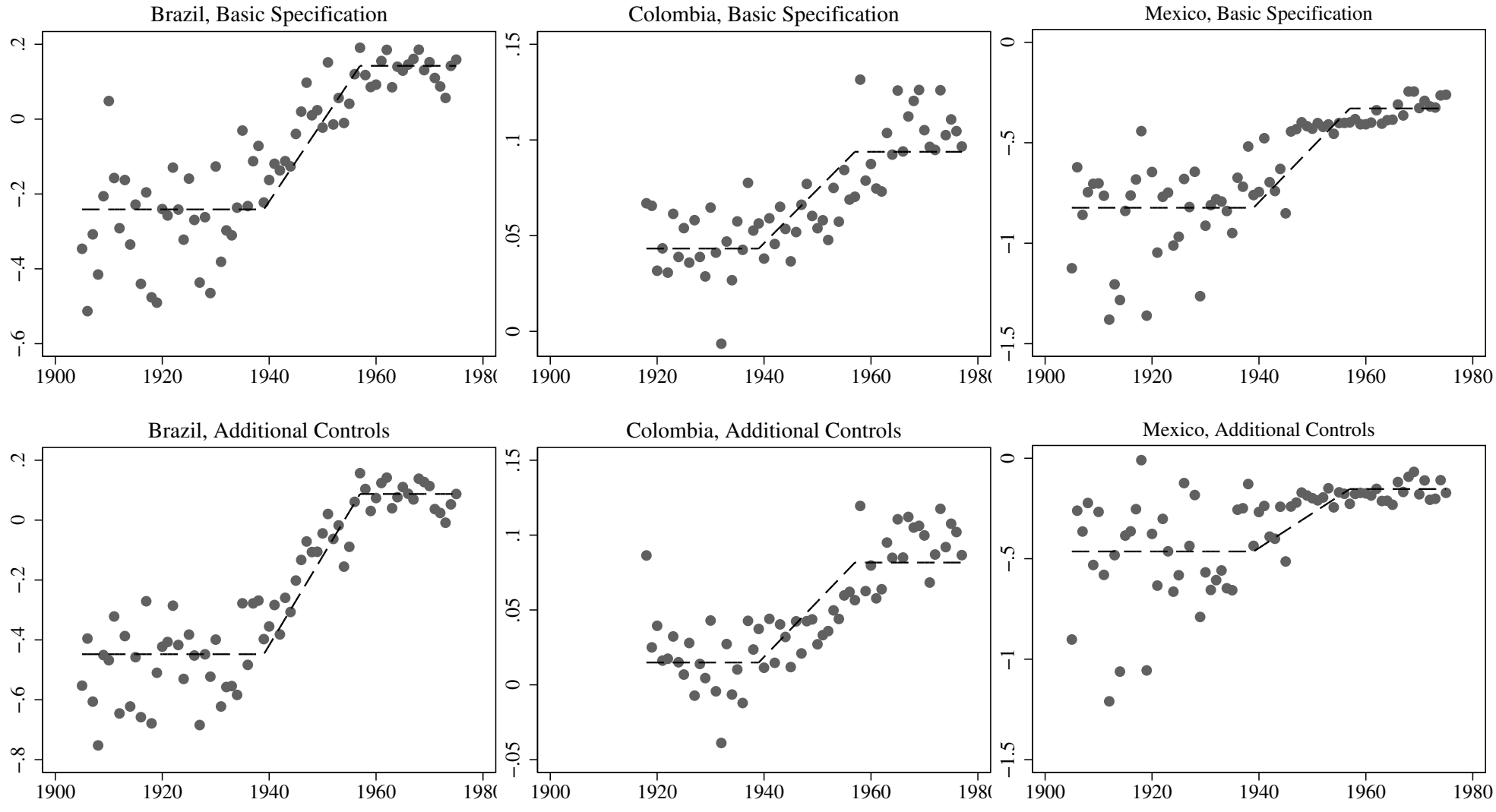
1900
1920
1940
1960
1980


Brazil, Basic Specification
Colombia, Basic Specification
Mexico, Basic Specification
Brazil, Additional Controls
Colombia, Additional Controls
Mexico, Additional Controls
1900
1920
1940
1960
1980

# Exposure versus Alternative Time-Series Process

Horserace:

$$\hat{\beta}_k = \alpha \ \text{Exp}_k + \sum_{i=1}^{n} \gamma_n k^n + \Phi(L)\hat{\beta}_k + \eta_k + \text{constant} + \epsilon_t^{ts}$$

# Exposure versus Alternative Time-Series Process

| Specification: | Outcome: | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Degree of Polynomial-Trend Control: | | 0 | 1 | 0 | 1 | 2 | 0 | 2 |
| Degree of Autoregressive Process: | | 0 | 0 | 1 | 1 | 0 | 2 | 2 |
| | | *Panel A: United States* | | | | | | |
| Basic | Occupational Income Score | 0.124 *** | 0.109 *** | 0.104 *** | 0.094 *** | 0.109 *** | 0.093 *** | 0.082 ** |
| | | (0.004) | (0.009) | (0.015) | (0.019) | (0.008) | (0.030) | (0.036) |
| Additional controls | Occupational Income Score | 0.061 *** | 0.150 *** | 0.128 *** | 0.101 *** | 0.131 *** | 0.120 *** | 0.080 * |
| | | (0.006) | (0.012) | (0.011) | (0.026) | (0.011) | (0.027) | (0.047) |
| Birthstate x census>1920 | Occupational Income Score | 0.071 *** | 0.150 *** | 0.133 *** | 0.099 *** | 0.131 *** | 0.026 ** | 0.100 ** |
| | | (0.005) | (0.010) | (0.009) | (0.022) | (0.008) | (0.015) | (0.040) |
| Basic | Duncan's Index | 0.162 *** | 0.126 *** | 0.138 *** | 0.113 *** | 0.139 *** | 0.121 ** | 0.114 ** |
| | | (0.007) | (0.015) | (0.022) | (0.031) | (0.014) | (0.050) | (0.060) |
| Additional controls | Duncan's Index | 0.088 *** | 0.184 *** | 0.058 *** | 0.154 *** | 0.172 *** | 0.041 | 0.113 |
| | | (0.010) | (0.018) | (0.018) | (0.044) | (0.017) | (0.030) | (0.079) |
| Birthstate x census>1920 | Duncan's Index | 0.099 *** | 0.181 *** | 0.067 *** | 0.159 *** | 0.168 *** | 0.053 ** | 0.139 ** |
| | | (0.007) | (0.014) | (0.012) | (0.031) | (0.013) | (0.023) | (0.063) |
| | | *Panel B: Brazil* | | | | | | |
| Basic | Log Total Income | 0.184 *** | 0.220 *** | 0.164 *** | 0.197 ** | 0.277 *** | 0.122 | 0.205 |
| | | (0.020) | (0.048) | (0.047) | (0.092) | (0.048) | (0.087) | (0.620) |
| Additional controls | Log Total Income | 0.348 *** | 0.437 *** | 0.308 *** | 0.405 *** | 0.486 *** | 0.268 * | 0.417 |
| | | (0.019) | (0.050) | (0.082) | (0.128) | (0.048) | (0.160) | (1.896) |
| Additional controls | Log Earned Income | 0.297 *** | 0.459 *** | 0.345 *** | 0.520 ** | 0.432 *** | 0.308 | 0.368 |
| | | (0.042) | (0.110) | (0.117) | (0.260) | (0.138) | (0.224) | (2.069) |
| Additional controls, drop 1960 census | Log Total Income | 0.226 *** | 0.133 ** | 0.190 *** | 0.088 | 0.201 *** | 0.132 | 0.161 |
| | | (0.023) | (0.061) | (0.058) | (0.120) | (0.055) | (0.125) | (0.714) |
| | | *Panel C: Colombia* | | | | | | |
| Basic | Industrial Income Score | 0.036 ** | 0.041 ** | 0.036 *** | 0.034 ** | 0.031 ** | 0.032 ** | 0.036 ** |
| | | (0.015) | (0.016) | (0.014) | (0.014) | (0.014) | (0.013) | (0.018) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Degree of Polynomial-Trend Control: | | 0 | 1 | 0 | 1 | 2 | 0 | 2 |
| Degree of Autoregressive Process: | | 0 | 0 | 1 | 1 | 0 | 2 | 2 |
| Specification: | Outcome: | | | | | | | |
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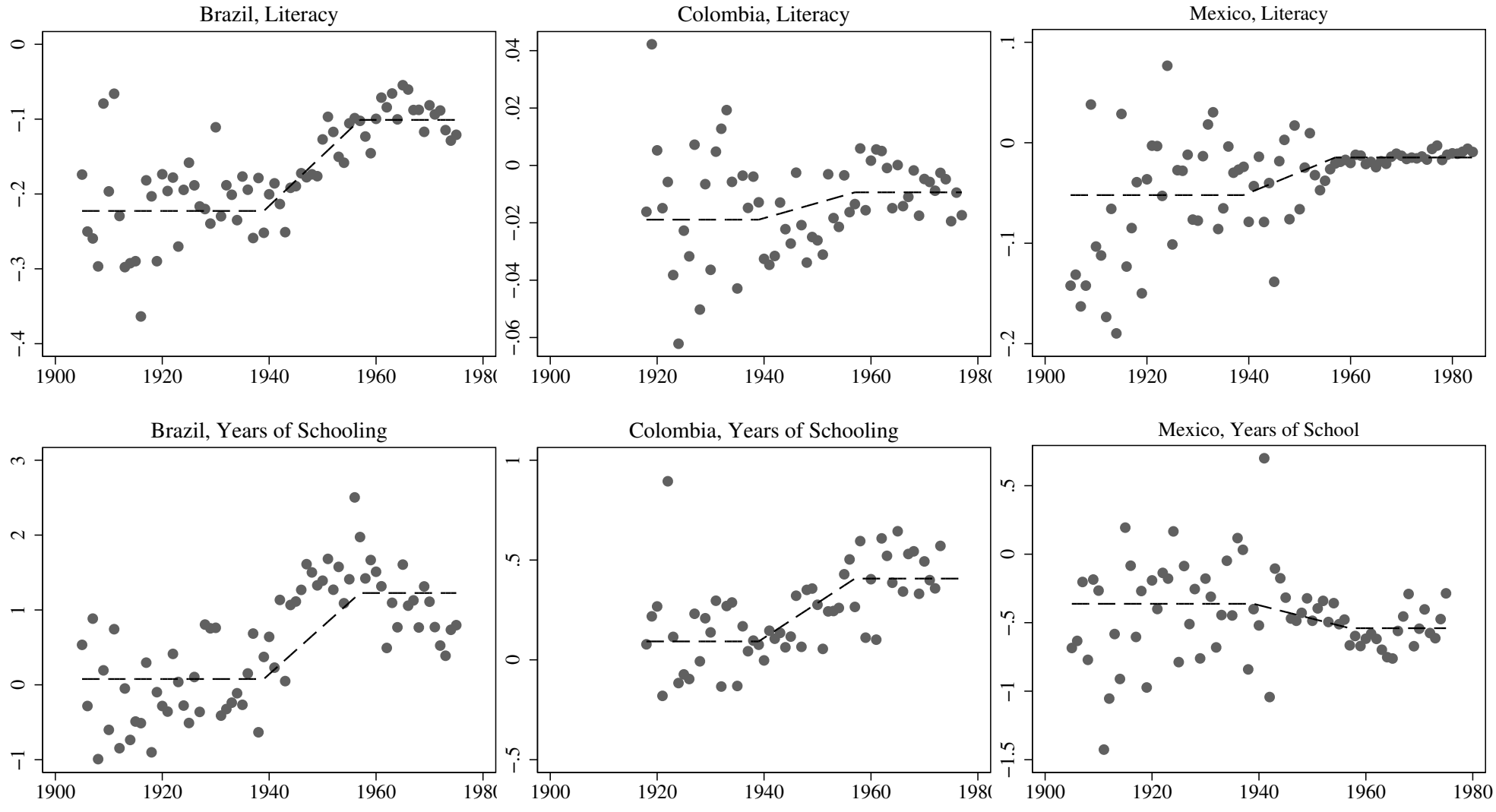
| | | (0.020) | (0.048) | (0.047) | (0.092) | (0.048) | (0.087) | (0.620) |
| Additional controls | Log Total Income | 0.348 *** | 0.437 *** | 0.308 *** | 0.405 *** | 0.486 *** | 0.268 * | 0.417 |
| | | (0.019) | (0.050) | (0.082) | (0.128) | (0.048) | (0.160) | (1.896) |
| Additional controls | Log Earned Income | 0.297 *** | 0.459 *** | 0.345 *** | 0.520 ** | 0.432 *** | 0.308 | 0.368 |
| | | (0.042) | (0.110) | (0.117) | (0.260) | (0.138) | (0.224) | (2.069) |
| Additional controls, drop 1960 census | Log Total Income | 0.226 *** | 0.133 ** | 0.190 *** | 0.088 | 0.201 *** | 0.132 | 0.161 |
| | | (0.023) | (0.061) | (0.058) | (0.120) | (0.055) | (0.125) | (0.714) |
| | | *Panel C: Colombia* | | | | | | |
| Basic | Industrial Income Score | 0.036 ** | 0.041 ** | 0.036 *** | 0.034 ** | 0.031 ** | 0.032 ** | 0.036 ** |
| | | (0.015) | (0.016) | (0.014) | (0.014) | (0.014) | (0.013) | (0.018) |
| Additional controls | Industrial Income Score | 0.063 *** | 0.047 ** | 0.053 *** | 0.025 ** | 0.032 ** | 0.037 ** | 0.021 ** |
| | | (0.019) | (0.023) | (0.018) | (0.018) | (0.020) | (0.016) | (0.020) |
| | | *Panel D: Mexico* | | | | | | |
| Basic | Log Earned Income | 0.253 *** | 0.162 * | 0.269 *** | 0.135 | 0.077 | 0.191 * | -0.001 |
| | | (0.057) | (0.068) | (0.094) | (0.169) | (0.052) | (0.108) | (0.535) |
| Additional controls | Log Earned Income | 0.231 *** | 0.155 * | 0.250 ** | 0.105 | 0.068 | 0.211 | 0.059 |
| | | (0.071) | (0.084) | (0.118) | (0.162) | (0.074) | (0.187) | (0.805) |
| Additional controls, drop 1960 census | Log Earned Income | 0.385 *** | 0.176 * | 0.365 *** | 0.142 | 0.176 * | 0.360 | 0.076 |
| | | (0.043) | (0.099) | (0.132) | (0.203) | (0.105) | (0.311) | (1.511) |

# Literacy and Years of Schooling

- Standard model: MB = MC of schooling
- Childhood malaria depresses both.
- Predictions ambiguous about inputs.
- To first order, outputs $\uparrow$.

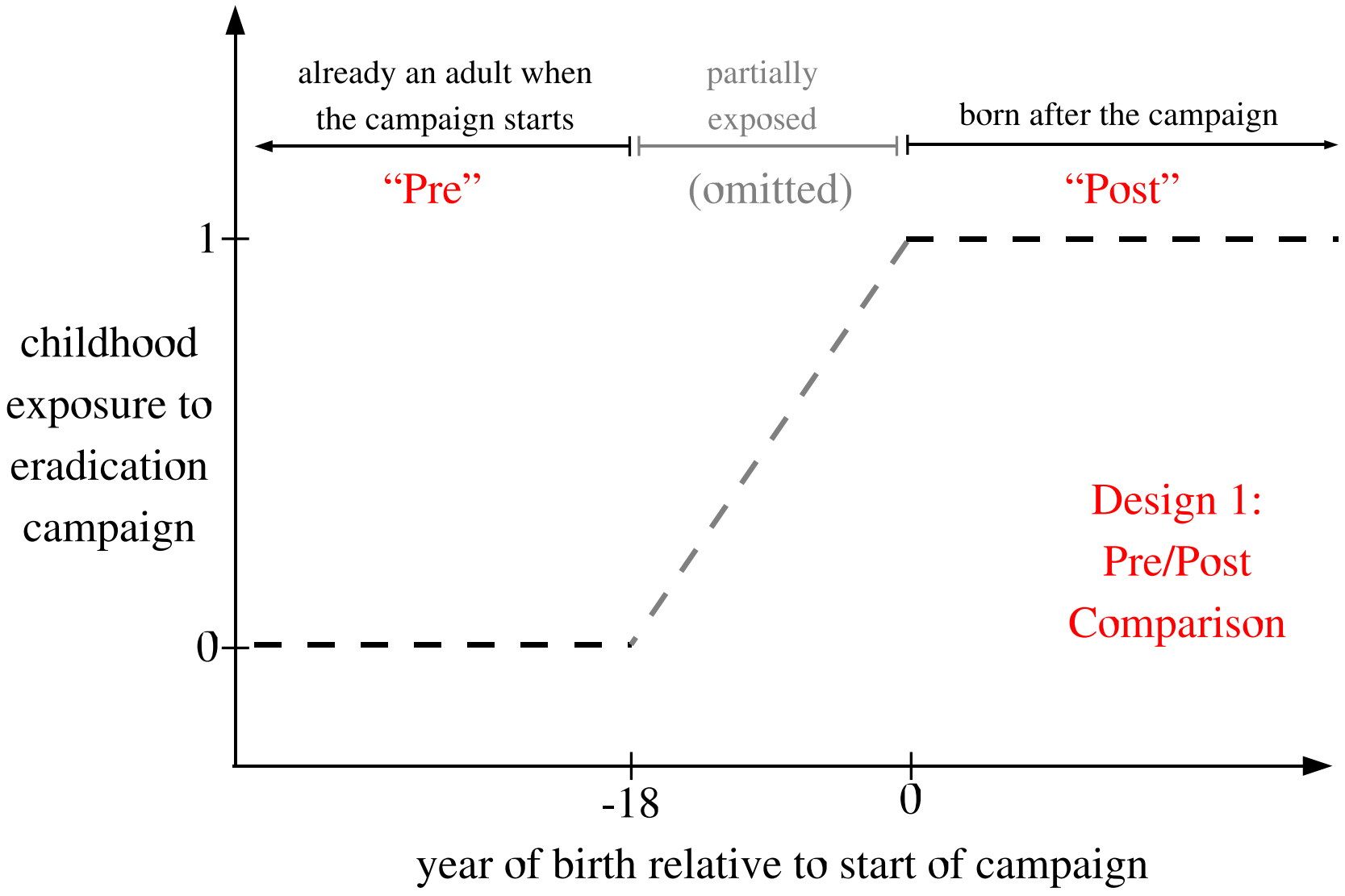

Brazil, Literacy
Colombia, Literacy
Mexico, Literacy
Brazil, Years of Schooling
Colombia, Years of Schooling
Mexico, Years of School
1900
1920
1940
1960
1980

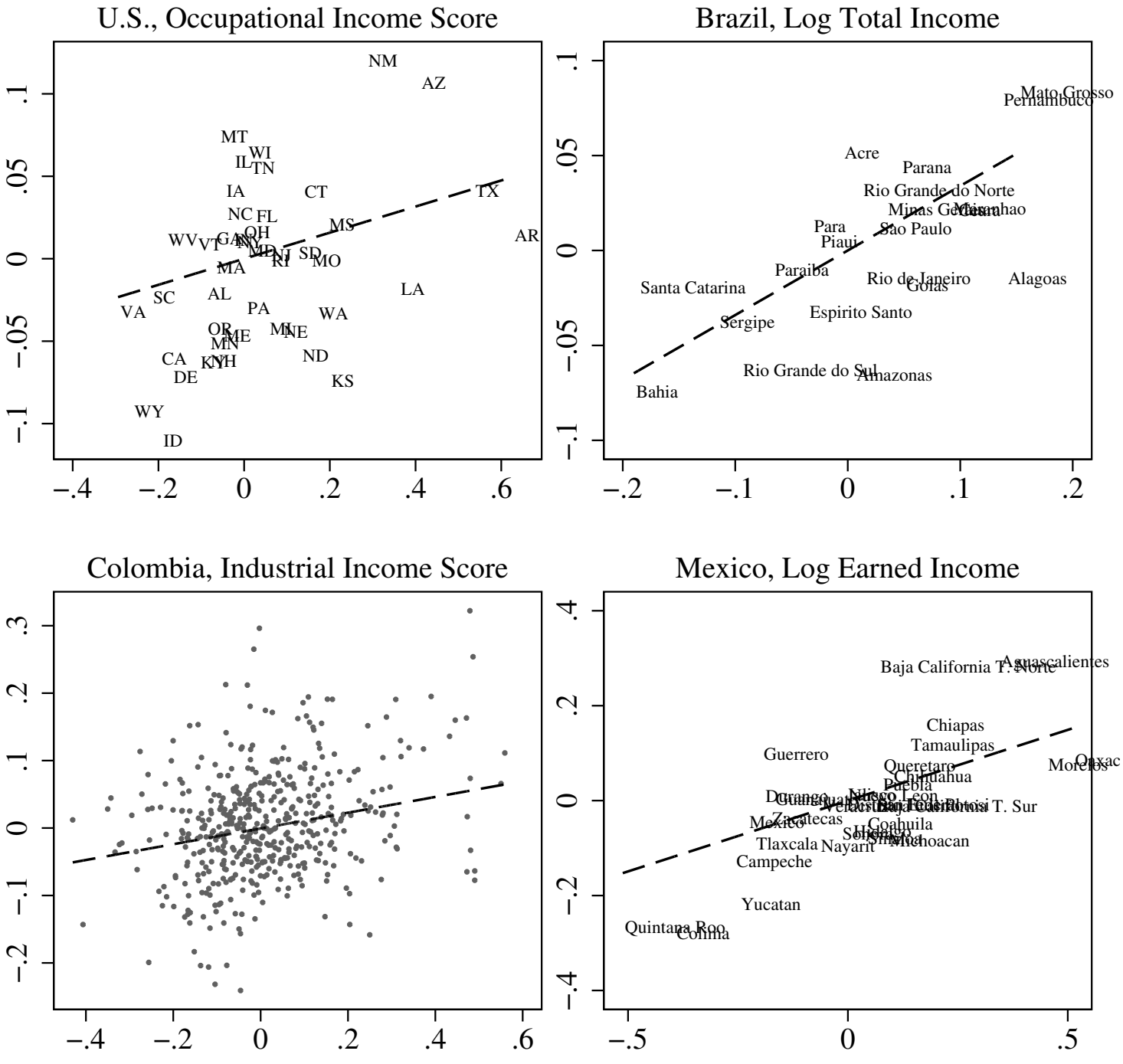
# Program for the Talk

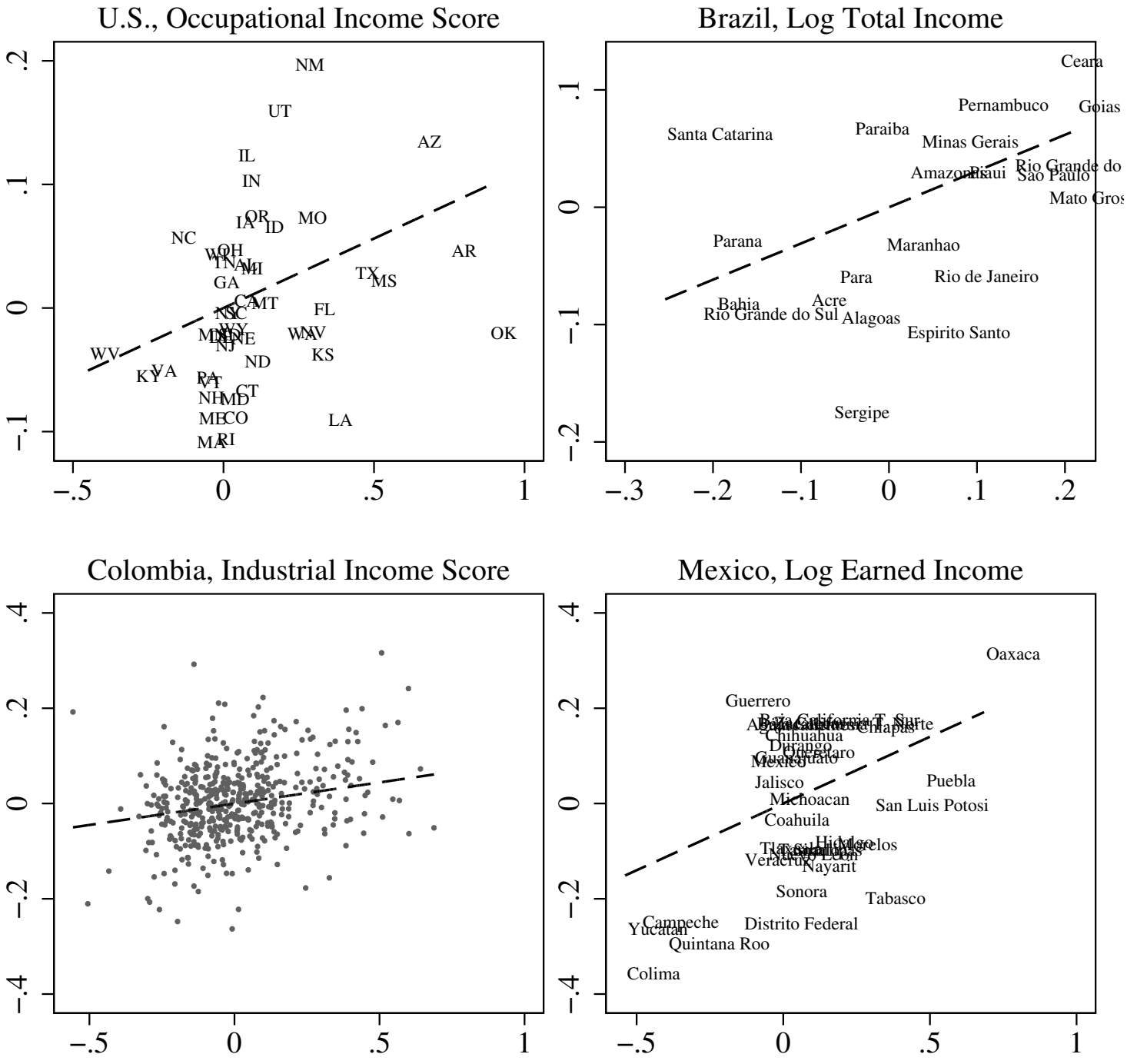
# Pre/Post Comparison

- Compare Cohorts: Exposed versus Unexposed
  1. Born before 1940 (US 1895)
  2. Born after 1955 (US 1920)
- Compare Areas: Malarious versus Nonmalarious Areas
- Difference in Difference (regression adjusted)

# Exposed versus Unexposed Cohorts




U.S., Occupational Income Score
NM
AZ
MT
WI
IL
TN
IA
CT
TX
NC
FL
MS
AR
WV
VT
OH
SD
MO
MA
RI
LA
SC
AL
VA
PA
WA
OR
ME
MN
NE
CA
KY
ND
DE
KS
WY
ID
−.4
−.2
0
.2
.4
.6
−.1
−.05
0
.05
.1
Brazil, Log Total Income
Mato Grosso
Pernambuco
Acre
Parana
Rio Grande do Norte
Minas Gerais
Maranhao
Para
Sao Paulo
Piaui
Paraiba
Rio de Janeiro
Alagoas
Santa Catarina
Goias
Espirito Santo
Sergipe
Rio Grande do Sul
Amazonas
Bahia
−.2
−.1
0
.1
.2
−.1
−.05
0
.05
.1
Colombia, Industrial Income Score
−.4
−.2
0
.2
.4
.6
−.2
−.1
0
.1
.2
.3
Mexico, Log Earned Income
Baja California T. Norte
Aguascalientes
Chiapas
Tamaulipas
Guerrero
Morelos
Oaxac
Queretaro
Chihuahua
Puebla
Durango
Nuevo Leon
T. Sur
Zacatecas
Mexico
Coahuila
Tlaxcala
Nayarit
Michoacan
Campeche
Yucatan
Quintana Roo
Colima
−.5
0
.5
−.4
−.2
0
.2
.4


U.S., Occupational Income Score
NM
UT
AZ
IL
IN
OR
IA
ID
MO
NC
OH
AR
TX
MS
GA
FL
OK
WV
KY
VA
KS
ND
CT
LA
RI
−.5
0
.5
1
−.1
0
.1
.2
Brazil, Log Total Income
Ceara
Pernambuco
Goias
Santa Catarina
Paraiba
Minas Gerais
Amazonas
Piaui
São Paulo
Rio Grande do
Mato Gros
Parana
Maranhao
Para
Rio de Janeiro
Bahia
Acre
Rio Grande do Sul
Alagoas
Espirito Santo
Sergipe
−.3
−.2
−.1
0
.1
.2
−.2
−.1
0
.1
Colombia, Industrial Income Score
−.5
0
.5
1
−.4
−.2
0
.2
.4
Mexico, Log Earned Income
Oaxaca
Guerrero
Chihuahua
Durango
Jalisco
Puebla
Michoacan
San Luis Potosi
Coahuila
Nayarit
Sonora
Tabasco
Campeche
Distrito Federal
Yucatan
Quintana Roo
Colima
−.5
0
.5
1
−.4
−.2
0
.2
.4

# Pre/Post Comparison

- Similar results to above.
- Effect not concentrated in a few outliers.
- Similar results for various subsets of controls.
- IV for measurement error: magnitude $\uparrow$
- Similar results: movers and nonmovers
- Similar results in US for mother's BPL

# Program for the Talk

# Interpretation: Reduced-form Income Differences

Compare most malarious to least malarious areas.

- United States (occscore): .13
- United States (Duncan) .16
- Brazil (total): .37
- Brazil (earned) .26
- Mexico (earned): .24
- Colombia (indscore): .10

# Approximating the Magnitude of the Decline in Malaria

| Type of Endemicity | |
|---|---|
| 1. None | 0% |
| 2. Hypoendemic | 0-10% |
| 3. Mesoendemic | 10-50% |
| 4. Hyperendemic | 50-75% |
| 5. Holoendemic | 75-100% |

Pre-eradication malaria...

- in the US ranged from "none" to "meso" $\Delta m \approx 0.3$
- in BCM ranged from "none" to "hyper" $\Delta m \approx 0.6$

# Interpretation: Indirect Least Squares

- Effect per probability of childhood infection?
- Normalize the reduced-form differences with the estimated decline in malaria
  - US: $\Delta y / \Delta m = .145/.3 \approx .47$
  - Brazil: $\Delta y / \Delta m = .37/.625 \approx .59$
  - Mexico: $\Delta y / \Delta m = .26/.625 \approx .41$
  - Colombia: $\Delta y / \Delta m = .07/.625 \approx .11$ (adjusted: 0.39)

# Program for the Talk

# Accounting for magnitude of the result

- Education: quantity, $+/-25\%$ ; return, $+/-100\%$
- Labor-market experience:

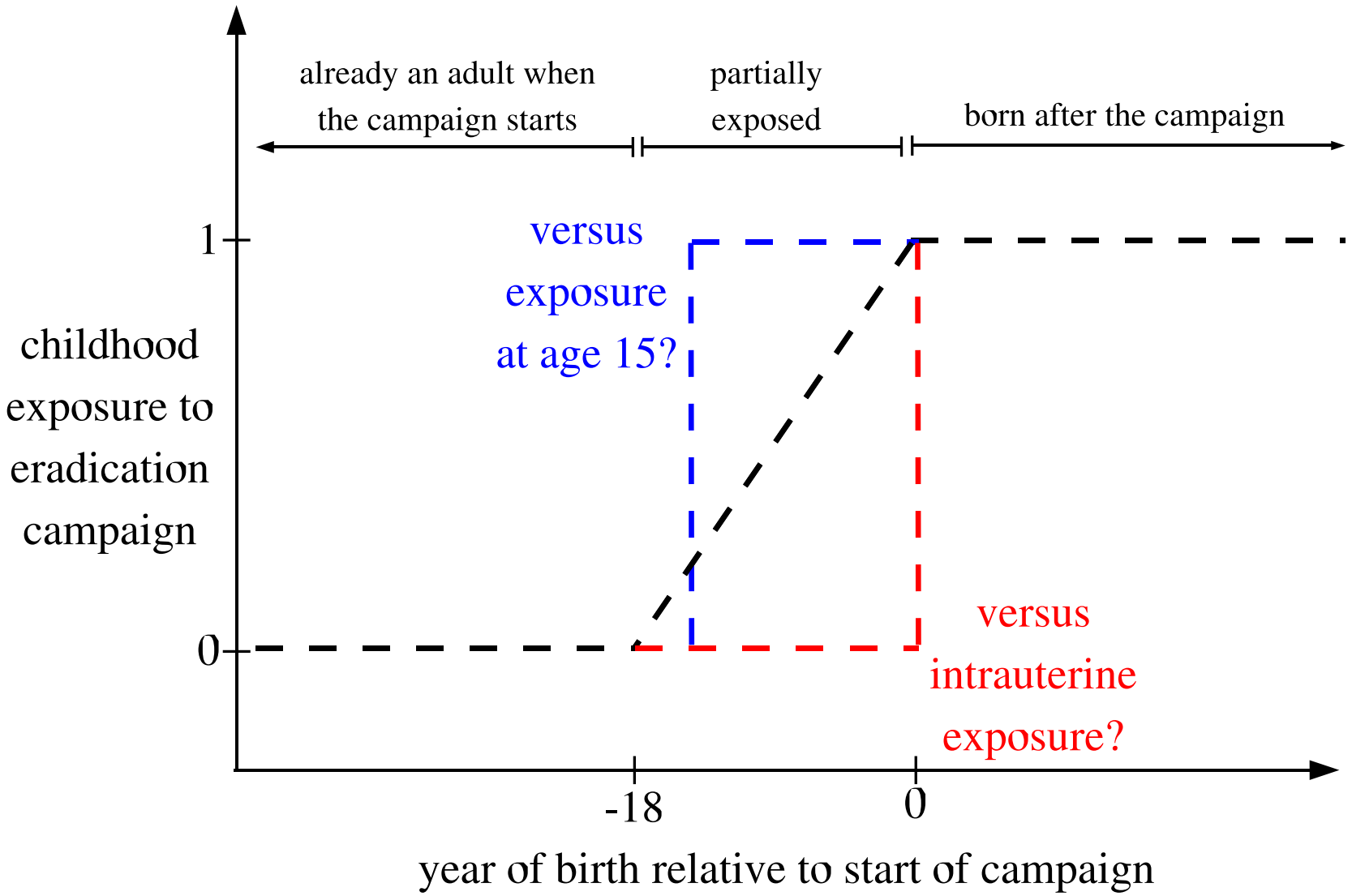
  hours $\downarrow$ ; returns $\uparrow$, explains $\approx 20\%$ of effect?

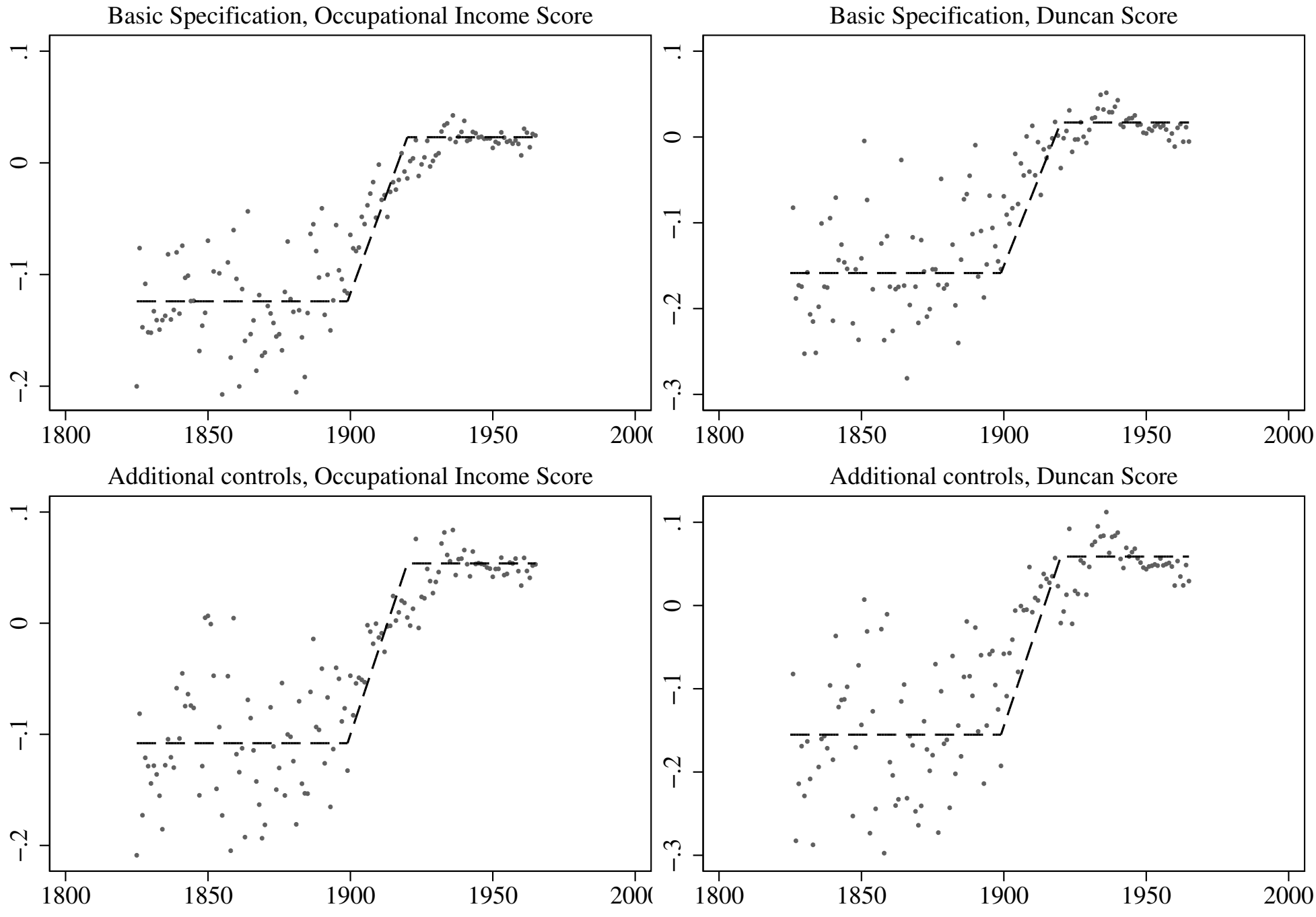
- Other vector-borne diseases: numbers too small.

  Colombia 1963: 22 cases of yellow fever, 21,245 cases of malaria

- Mortality selection: implausible. $30\% \times 30\% = 9\%$.
- *falciparum versus vivax*
- The timing of childhood exposure
- Spillovers

# Childhood Exposure to Eradication Campaign




Basic Specification, Occupational Income Score
Basic Specification, Duncan Score
Additional controls, Occupational Income Score
Additional controls, Duncan Score
1800
1850
1900
1950
2000
.1
0
−.1
−.2
−.3

# Program for the Talk

# Regional comparisons

Between North and South (US):

- 1900 gap in log(GDP) was 0.75
- 10–20% infection ; effect of 0.6 on income
- $\Rightarrow$ 8–17% of the gap

Between US and LatAm:

- 1950 gap in log(GDP) was 1.5–2
- 30-40% infection ; effect of 0.6 on income
- $\longrightarrow$ 10-16% of the gap

# Comparison with macro estimates

- Me: $\partial \log Y / \partial \text{Prob(infection)} \approx -0.6$
- Sachs & co.: $\partial \log Y / \partial \text{Prob(infection)} \approx -2.15$
- About 25% of the macro estimate.
- But note about *falciparum*

# Summary

- Large drop in malaria, circa 1920 in the US South and circa 1950 in LatAm
- Quasiexogenous in that it results from external factors
- Nonmalarious areas serve as a comparison group
- Faster cross-cohort growth in literacy and income in malaria-prone areas; Mixed evidence for education
- Coincident with childhood exposure to the program

# Open questions

- General equilbrium effects
- Interaction effects
- Vivax versus Falciparum
- Related evidence on parasitic disease

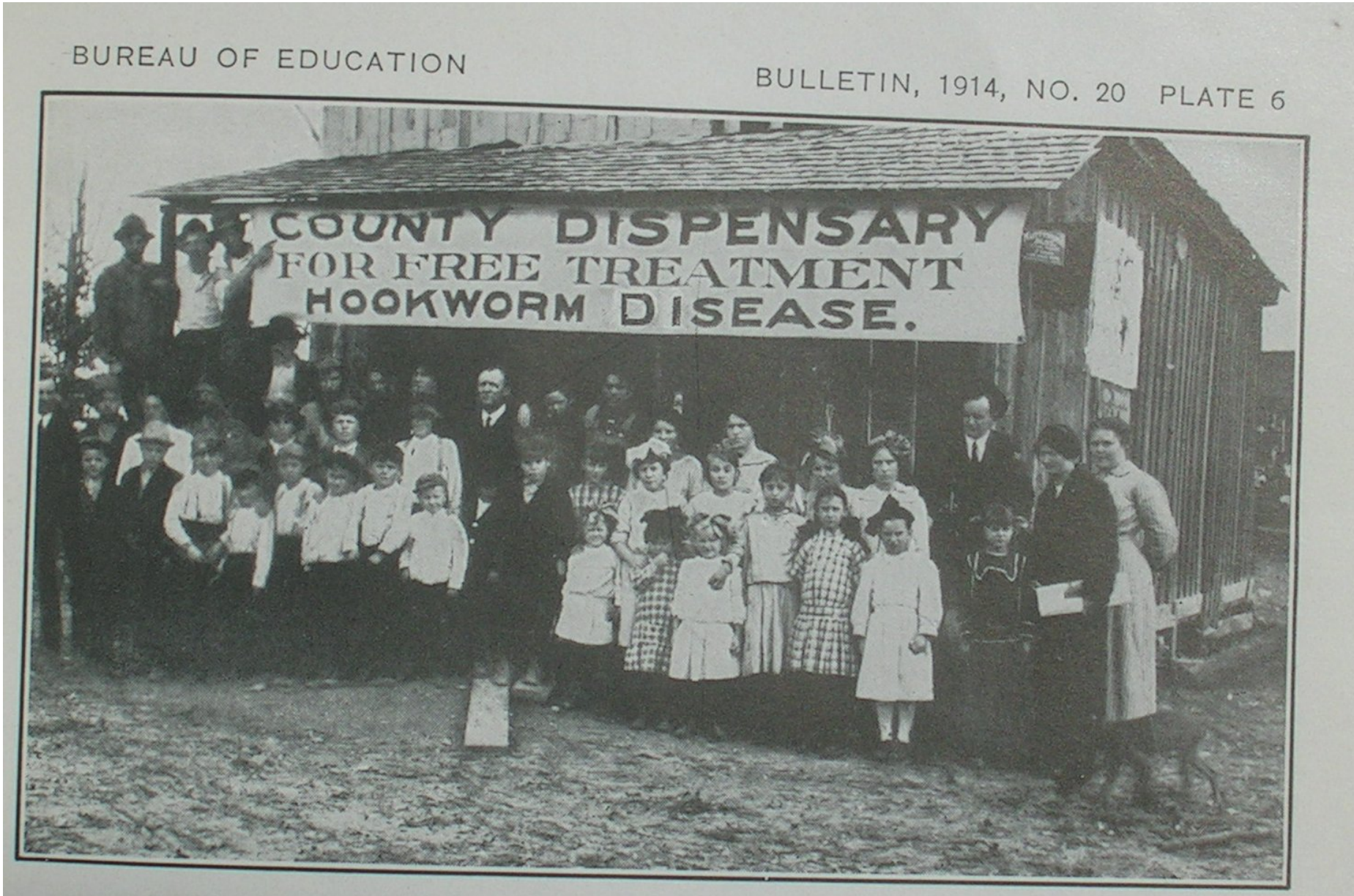
# Hookworm Eradication in the U.S. South

Before 1910, forty percent of children in the South were infected with hookworm.

But almost nobody knew about it!

# Rockefeller takes on Hookworm, *circa* 1910.

# Rockefeller Campaign: Dispensaries

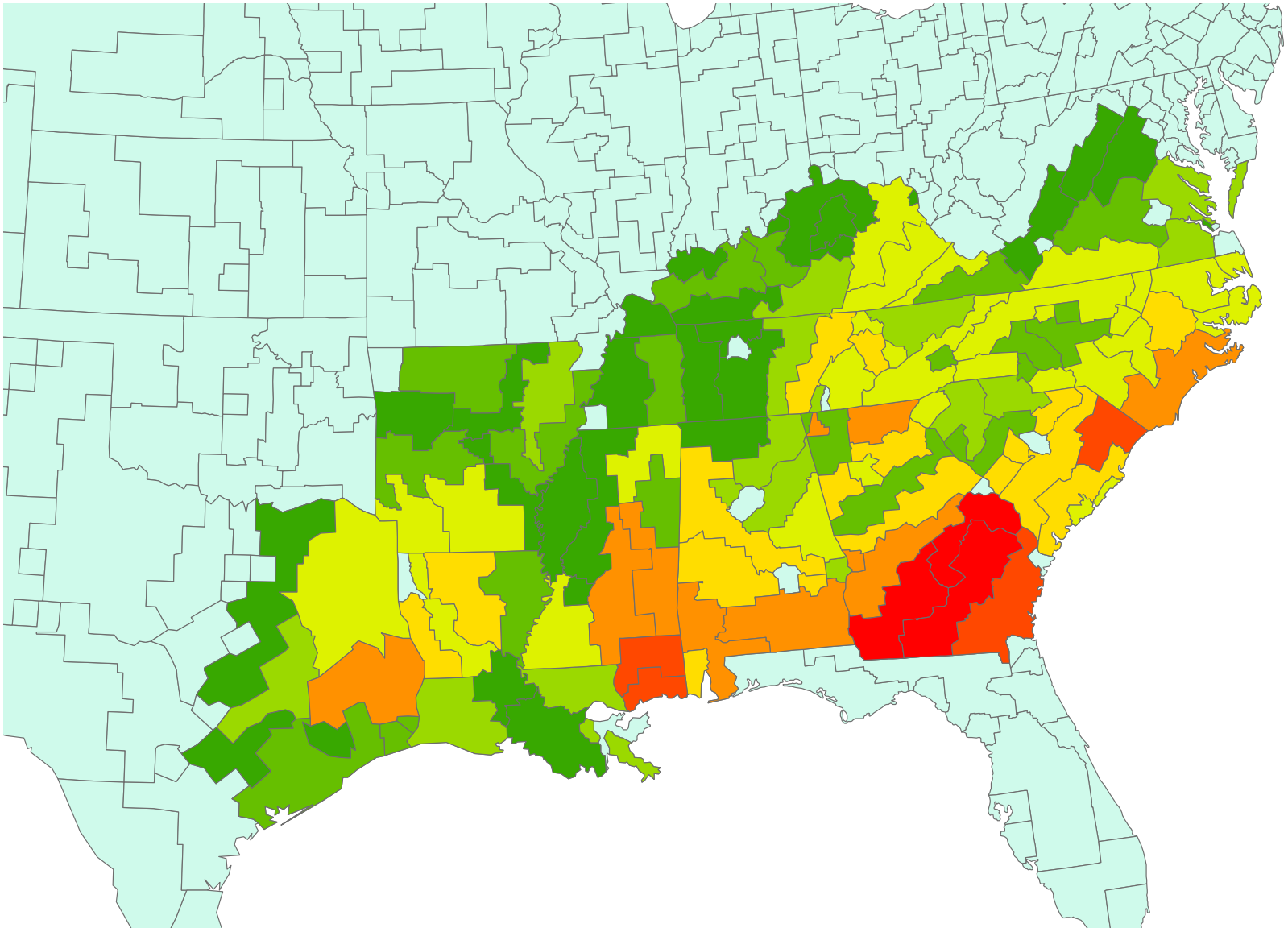


# Rockefeller Campaign: Exams and Treatment

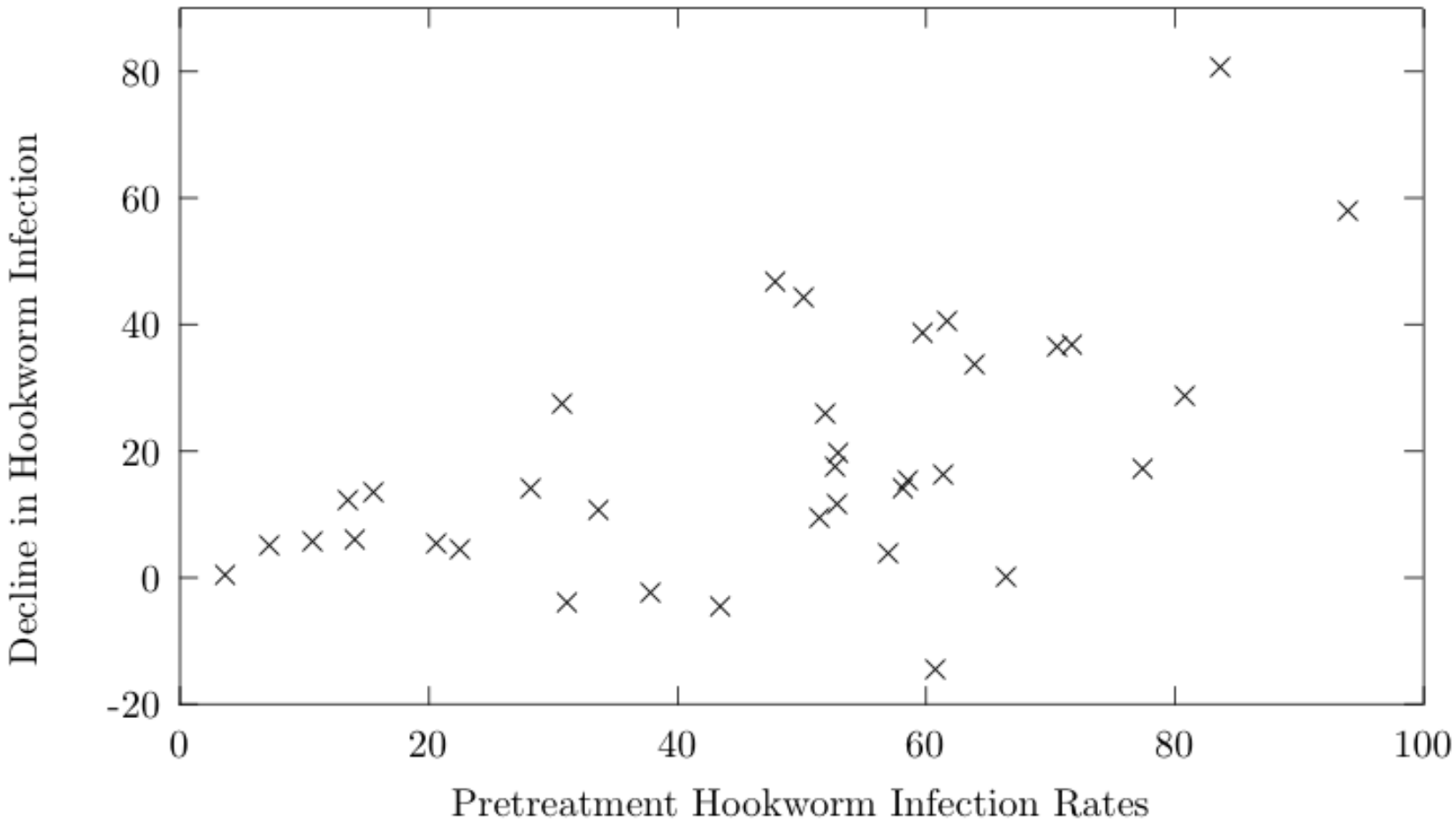
# Rockefeller Campaign: Education

# There was substantial heterogeneity across areas, largely due to soil type.

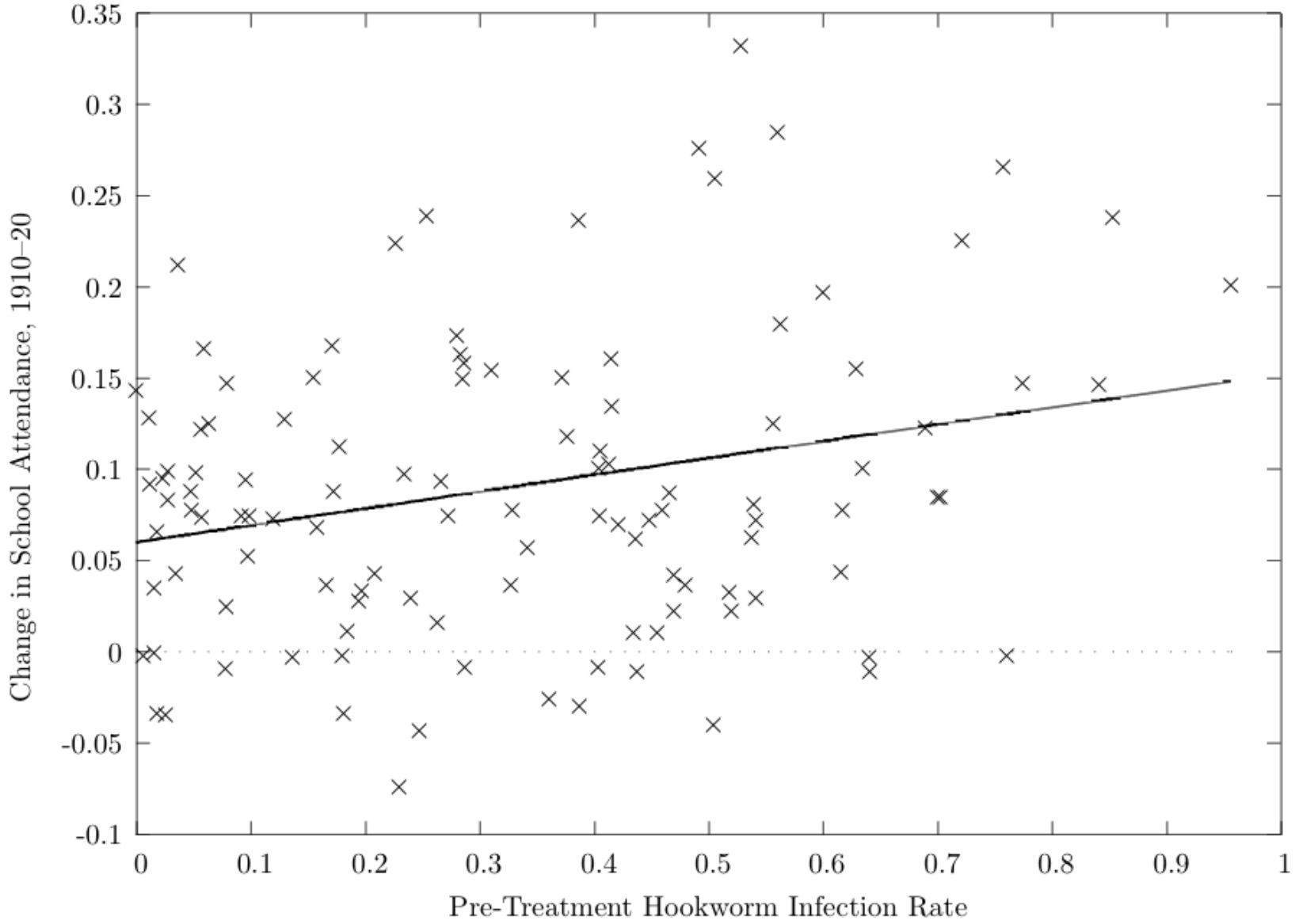
(red = more infection. green = less. blue = no data)



# Highly Infected Areas Saw Greater Declines in Hookworm

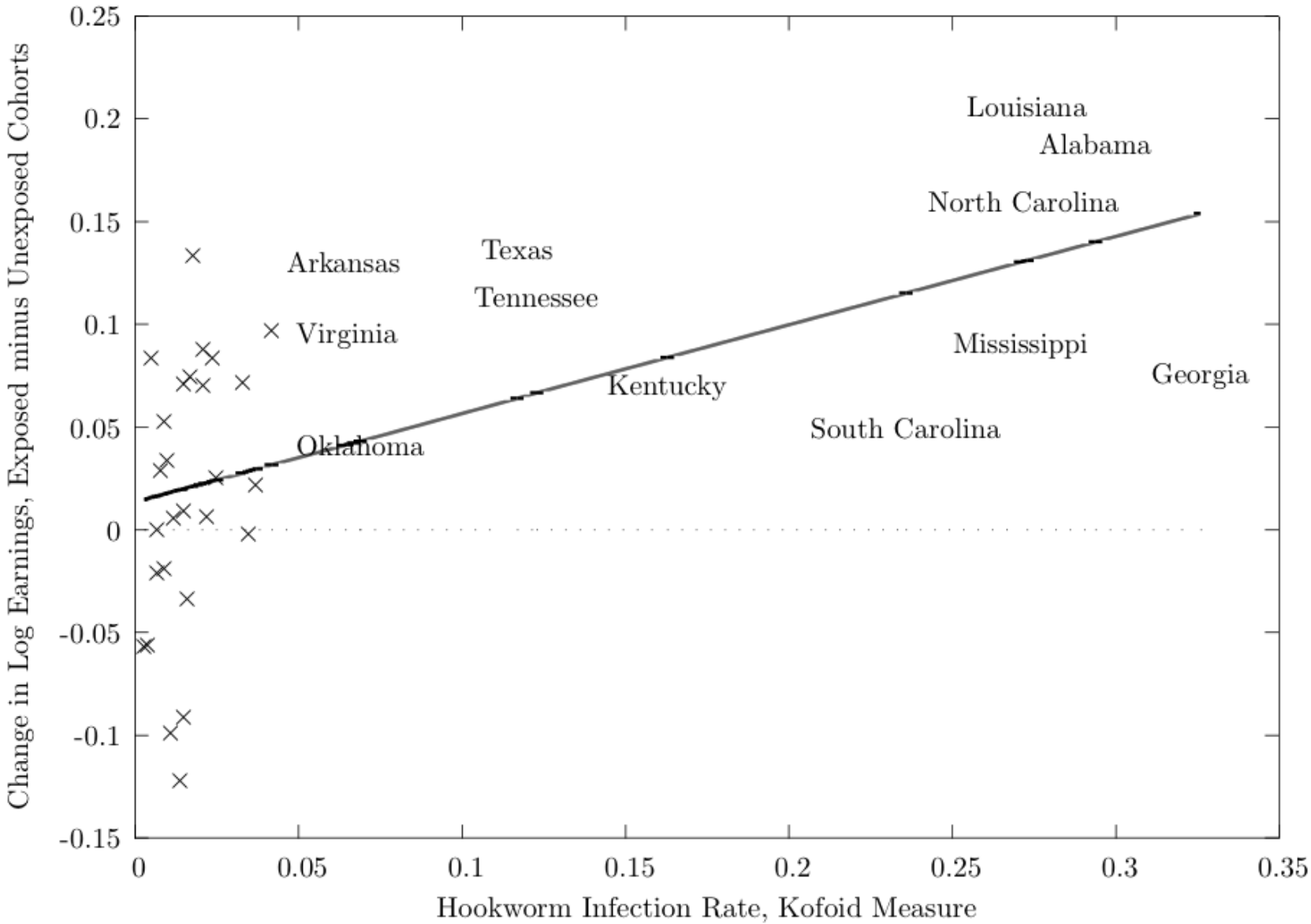


# Highly Infected Areas Saw Greater Increases in School Attendance

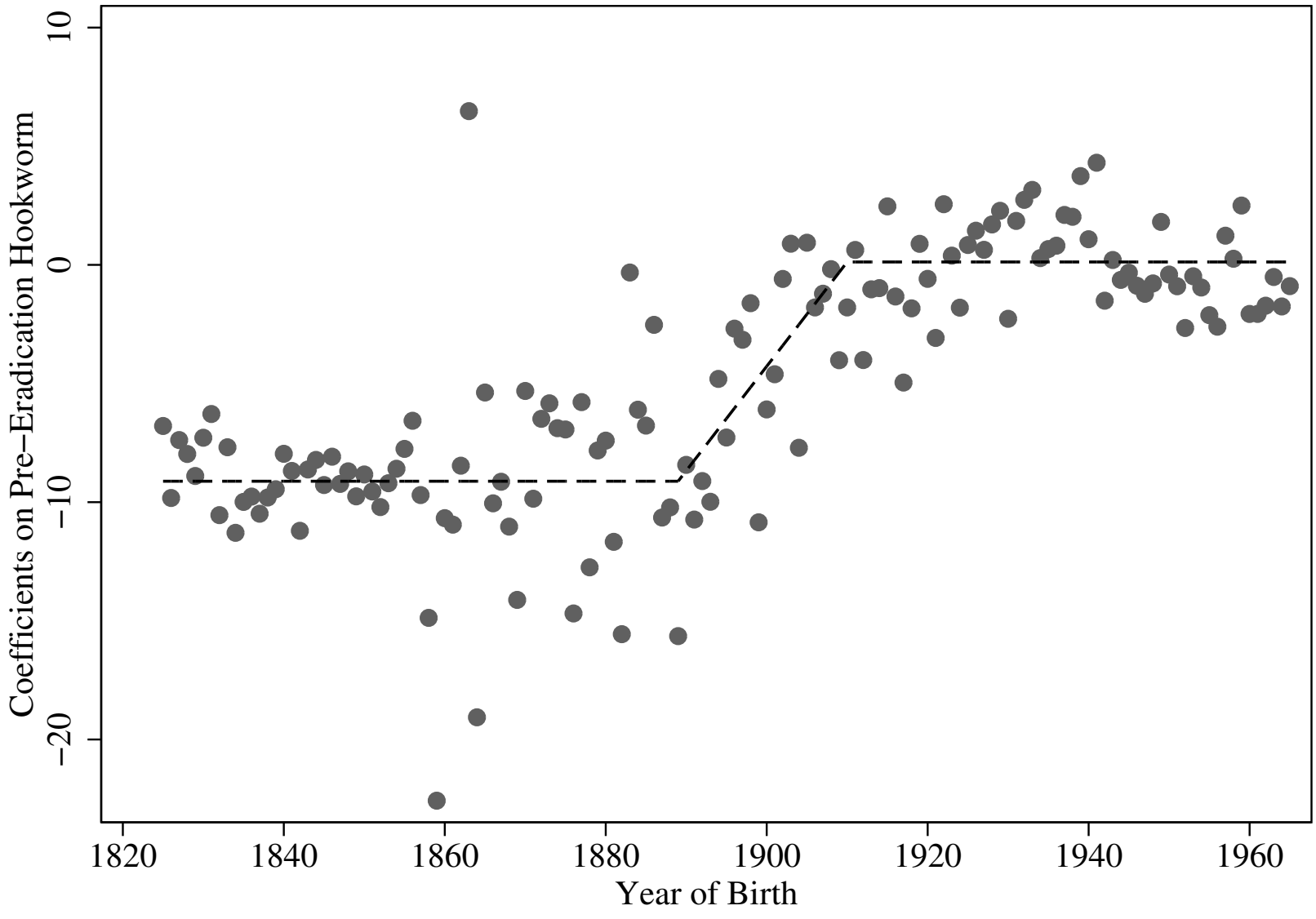


# The Shift in School Attendance Coincided with the Rockefeller Anti-Hookworm Campaign

# Areas with High Pre-Eradication Hookworm Saw Faster Cross-Cohort Growth in Income.



# The Shift in Income Coincided with Childhood Exposure to Hookworm (the dashed line)

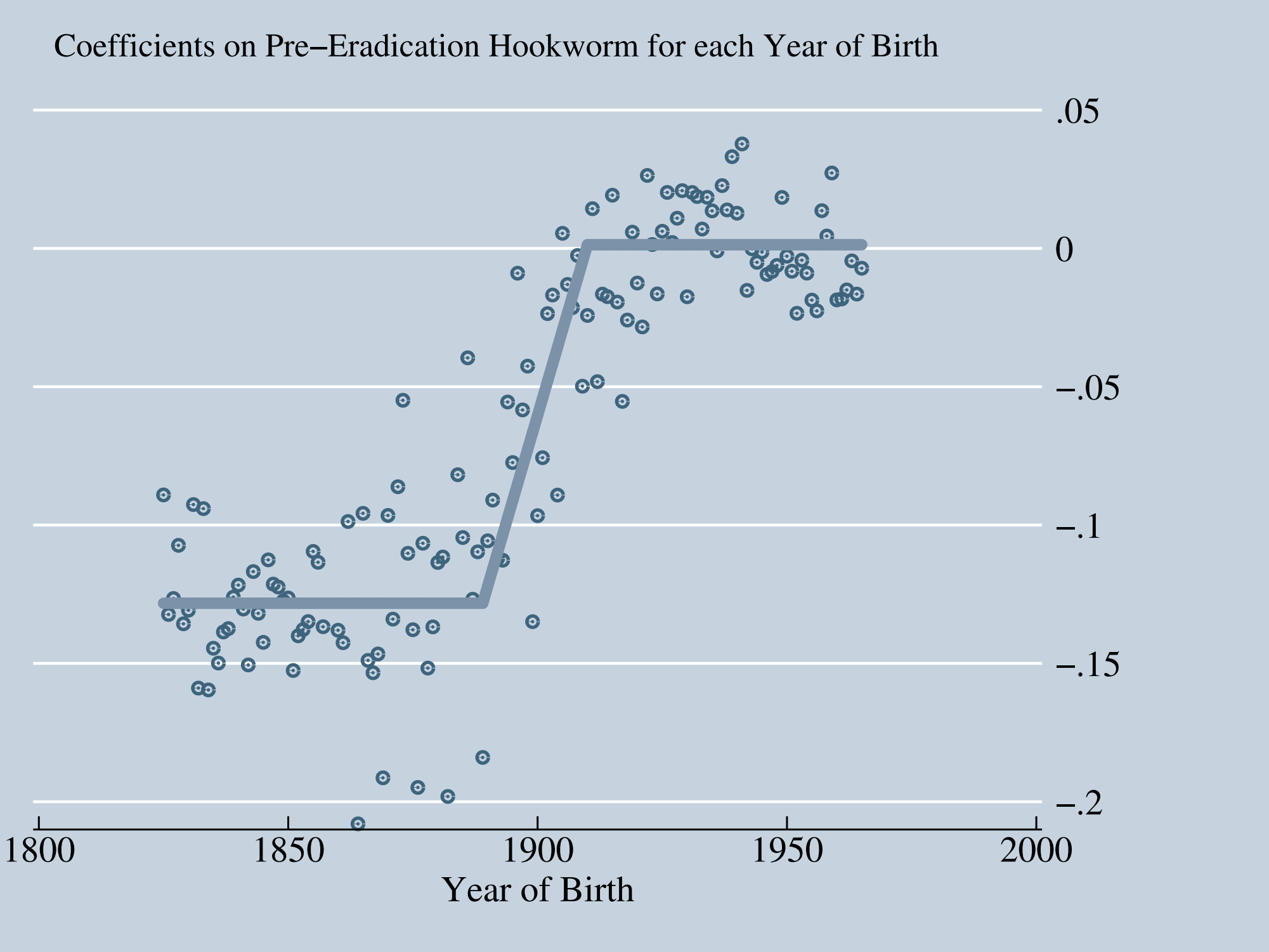


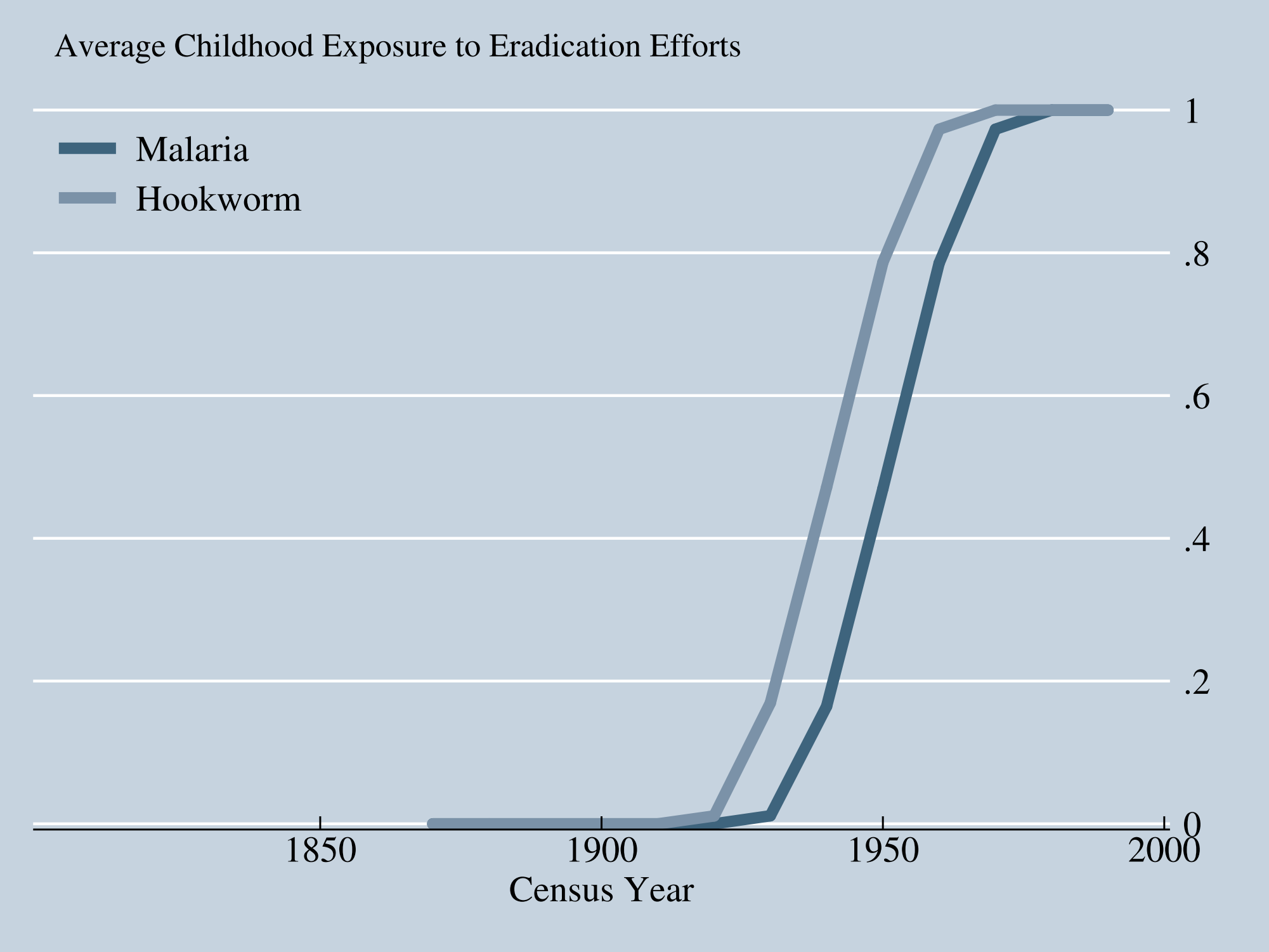
# General equilibrium effects

- Do healthy workers displace unhealthy workers?
- Healthy workers raise the productivity of those around them?

Aggregate: direct + spillovers

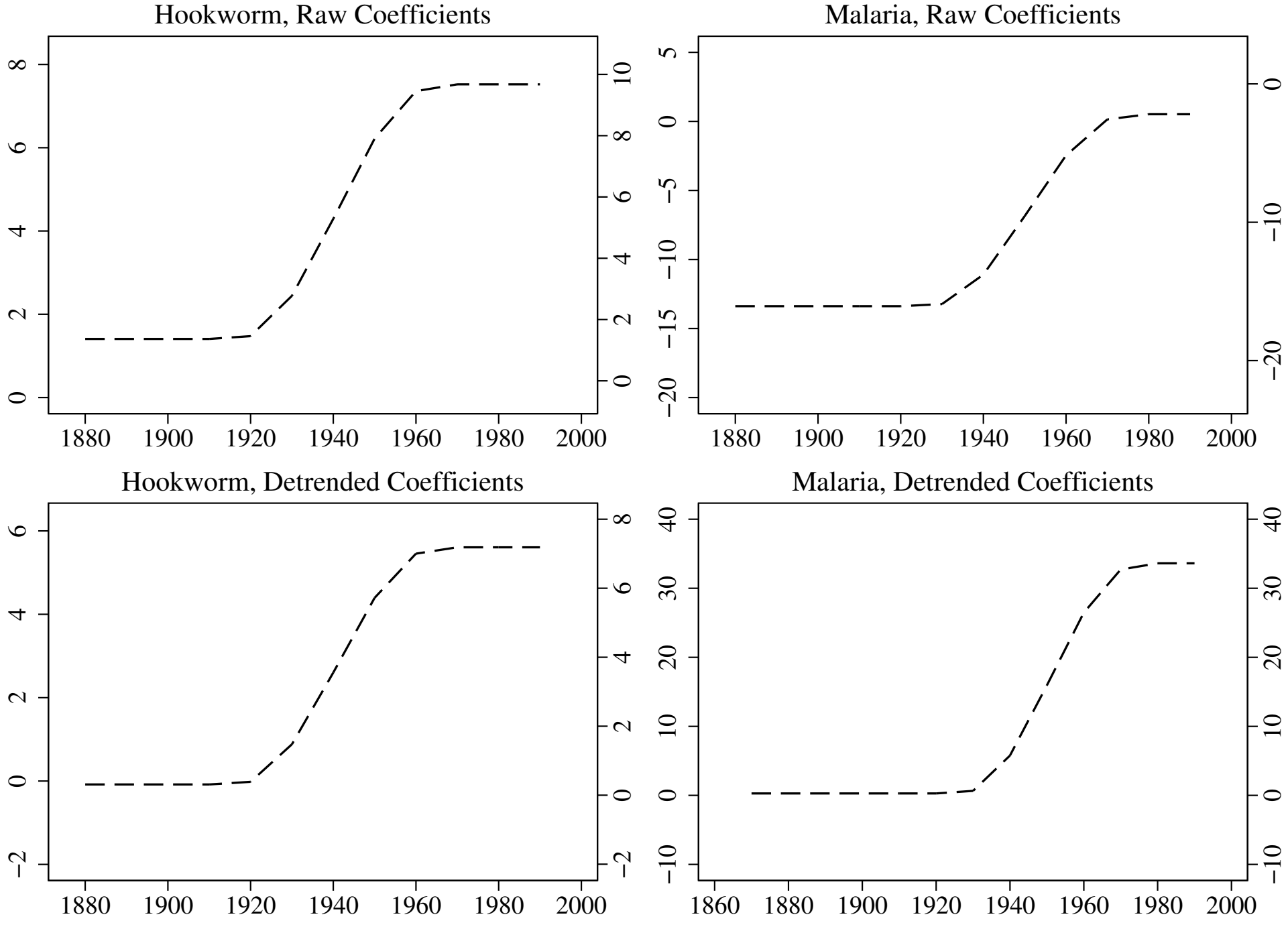
Bleakley (2007) "Spillovers and Aggregate Effects of Health Capital: Evidence from Campaigns Against Parasitic Disease in the Americas."

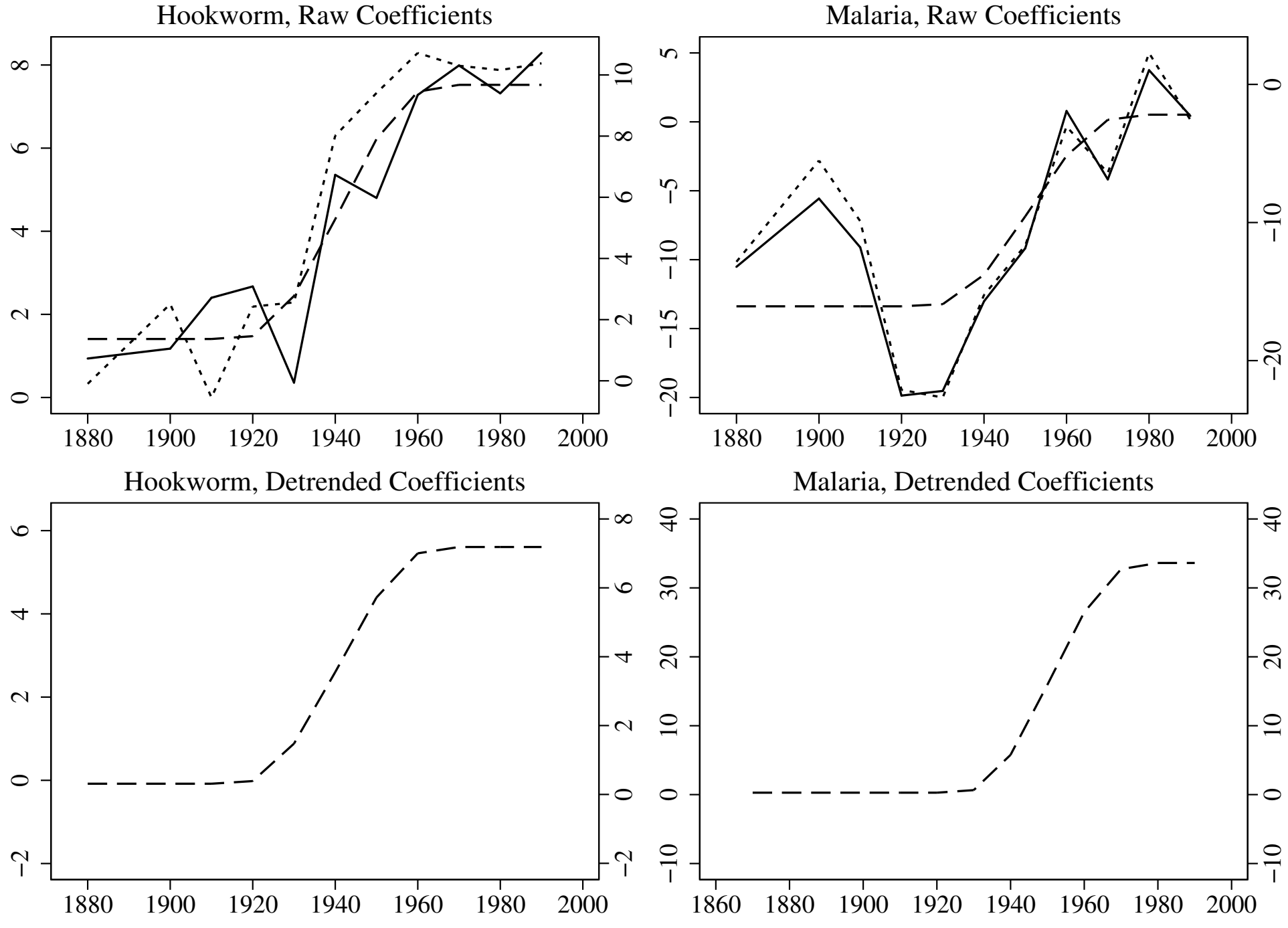

Coefficients on Pre−Eradication Hookworm for each Year of Birth
.05
0
−.05
−.1
−.15
−.2
1800
1850
1900
1950
2000
Year of Birth

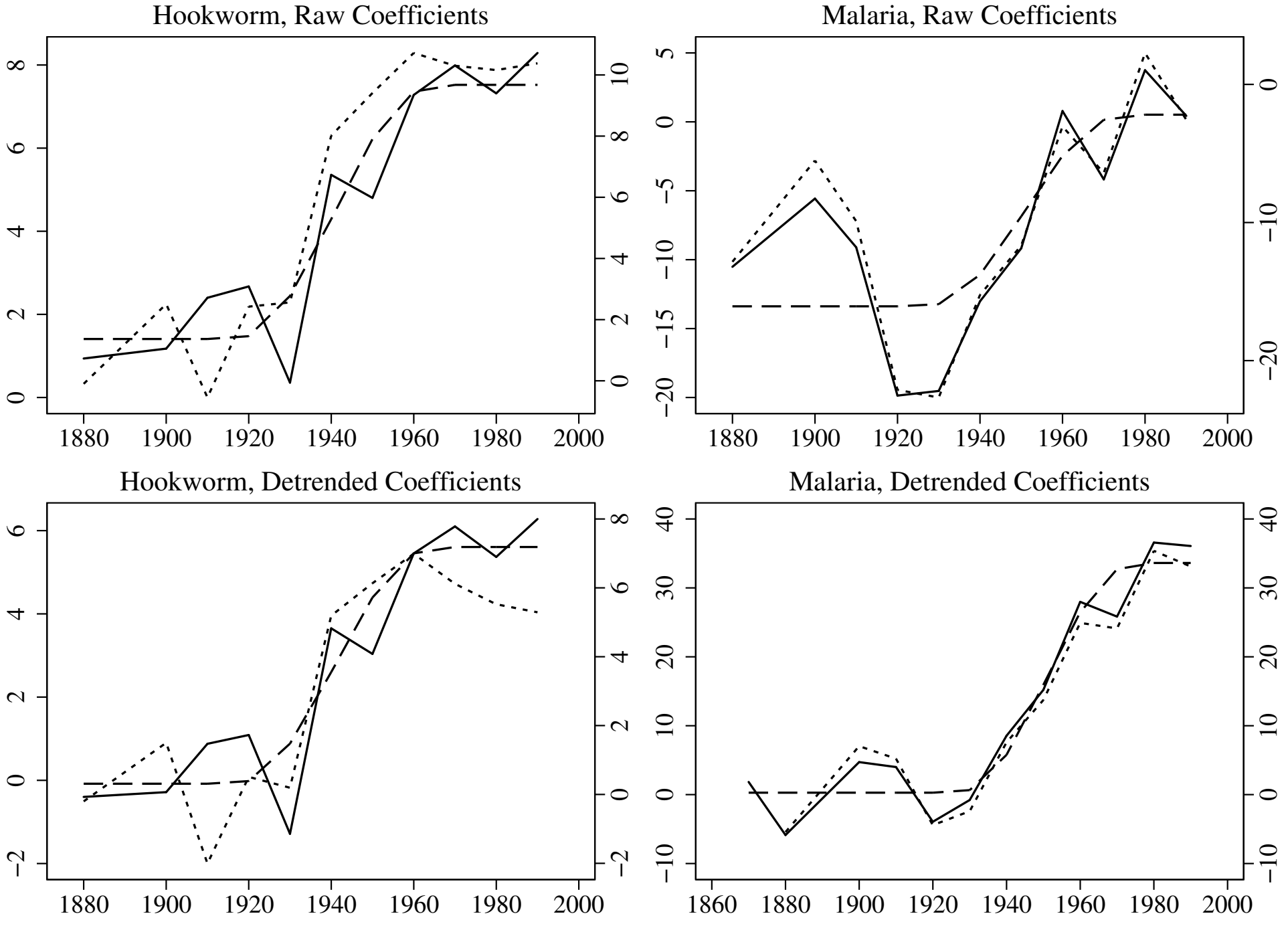

Average Childhood Exposure to Eradication Efforts
Malaria
Hookworm
1
.8
.6
.4
.2
0
1850
1900
1950
2000
Census Year

# Specification: Spillovers

- Estimate model with period-specific coefficients on regressors.
- Absorb all cohort effects (YOB $\times$ birthplace).
- Report the beta's on pre-campaign hookworm and malaria by census year.
- Independent regressors:
  1. Basic: region dummies, Lebergott's measure of 1909 unskilled wages, and both diseases.
  2. Full: basic, plus the following: child mortality, 1890; infant mortality, 1935; fraction urban, 1900; fraction of adults literate, 1910; doctors per capita, 1898; fraction black, 1910; male unemployment rate, 1930; fertility rate, 1880.


Hookworm, Raw Coefficients
Malaria, Raw Coefficients
Hookworm, Detrended Coefficients
Malaria, Detrended Coefficients
1860
1880
1900
1920
1940
1960
1980
2000


Hookworm, Raw Coefficients
Malaria, Raw Coefficients
Hookworm, Detrended Coefficients
Malaria, Detrended Coefficients
1860
1880
1900
1920
1940
1960
1980
2000


Hookworm, Raw Coefficients
Malaria, Raw Coefficients
Hookworm, Detrended Coefficients
Malaria, Detrended Coefficients
1860
1880
1900
1920
1940
1960
1980
2000

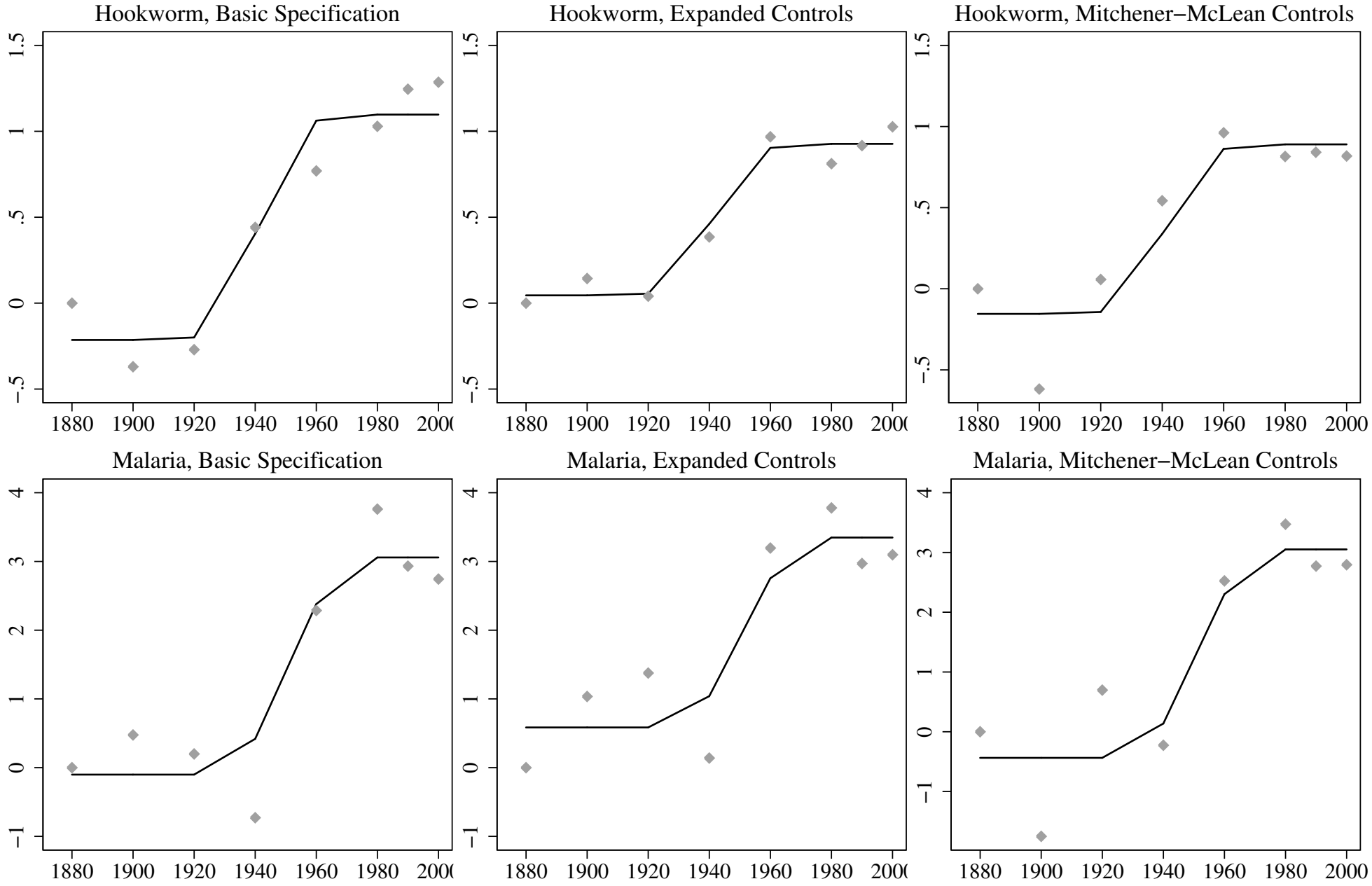
# Data and Specification: Aggregate

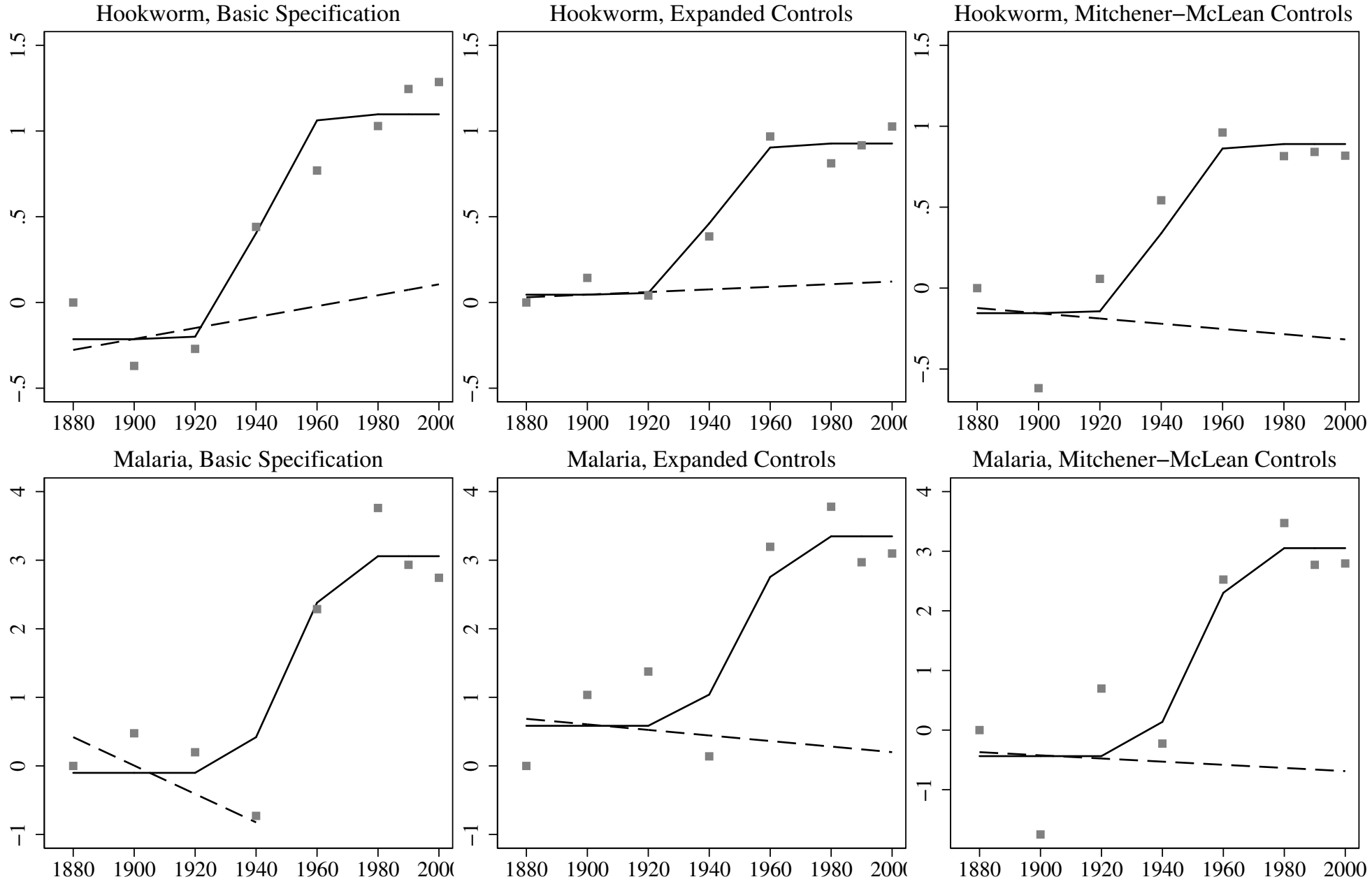
Data:

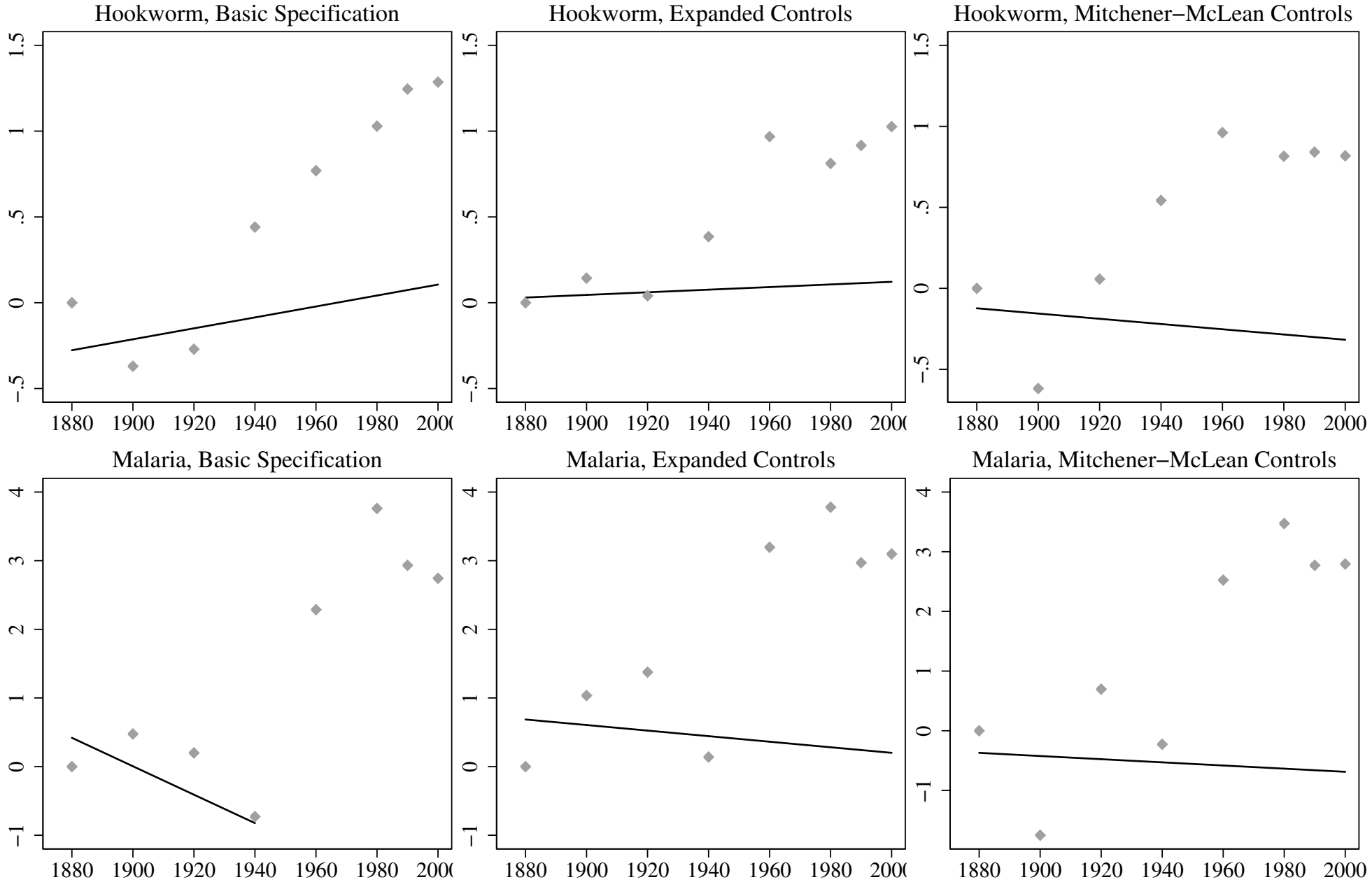
- Real personal income per capita
- 1880, 1900, 1920, 1940, 1960, 1980, 2000
- By state (plus the then territories, except Okla. 1880)
- Source: Mitchener/McLean, plus my extension for 2000.

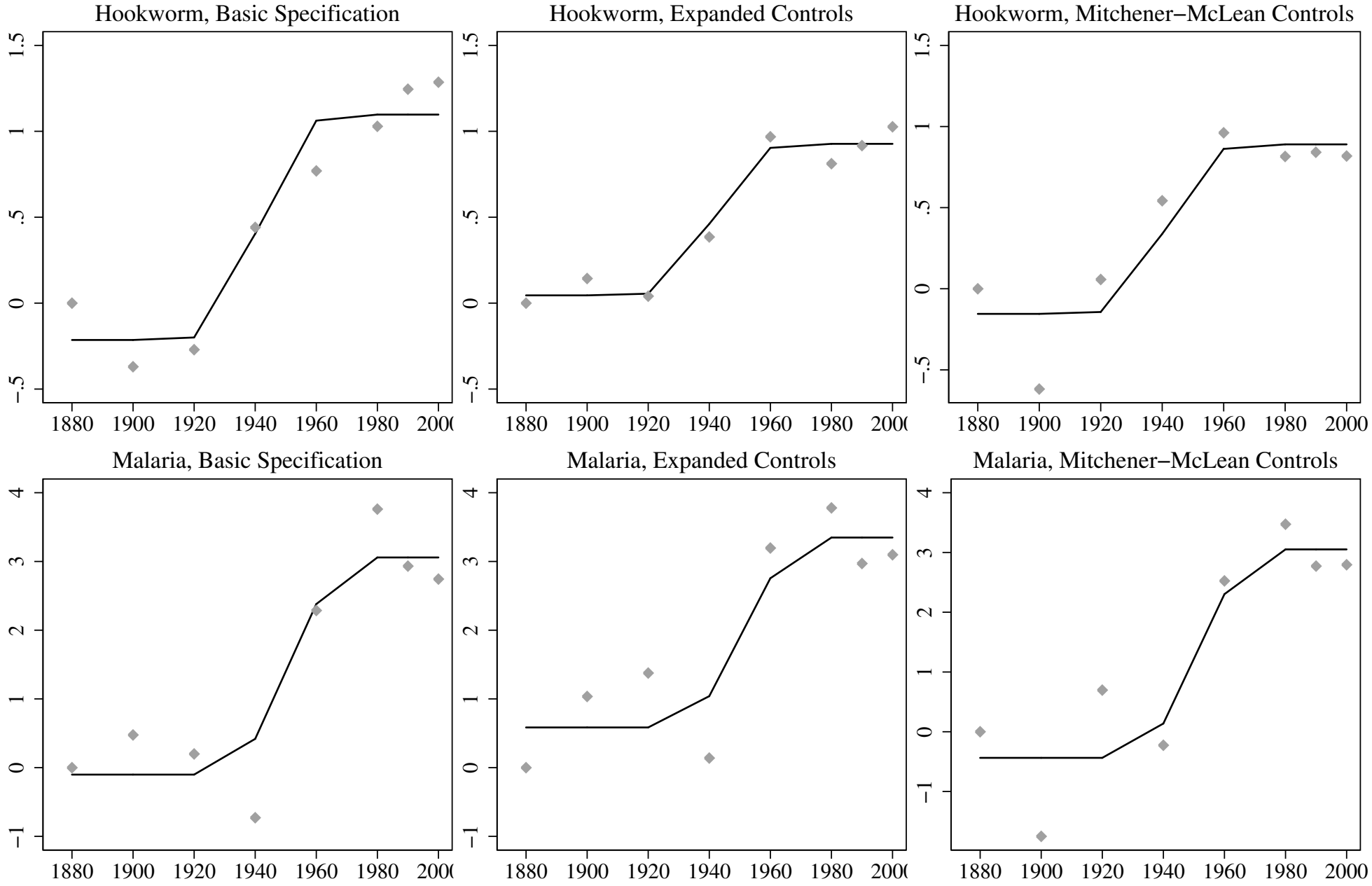
Specification:

- For each period, a cross-sectional regression.
- Report the beta's on pre-campaign hookworm and malaria.
- Independent, time-invariant regressors:
  1. Basic: region dummies, Lebergott's measure of 1909 unskilled wages, and both diseases.
  2. Full: basic, plus the following: child mortality, 1890; infant mortality, 1935; fraction urban, 1900; fraction of adults literate, 1910; doctors per capita, 1898; fraction black, 1910; male unemployment rate, 1930; fertility rate, 1880.
  3. Mitchener-McLean: basic, plus the following: fraction employed in mining, 1880; fraction enslaved, 1860; dummy of access to ocean or great lakes; Dummies for colonial origin

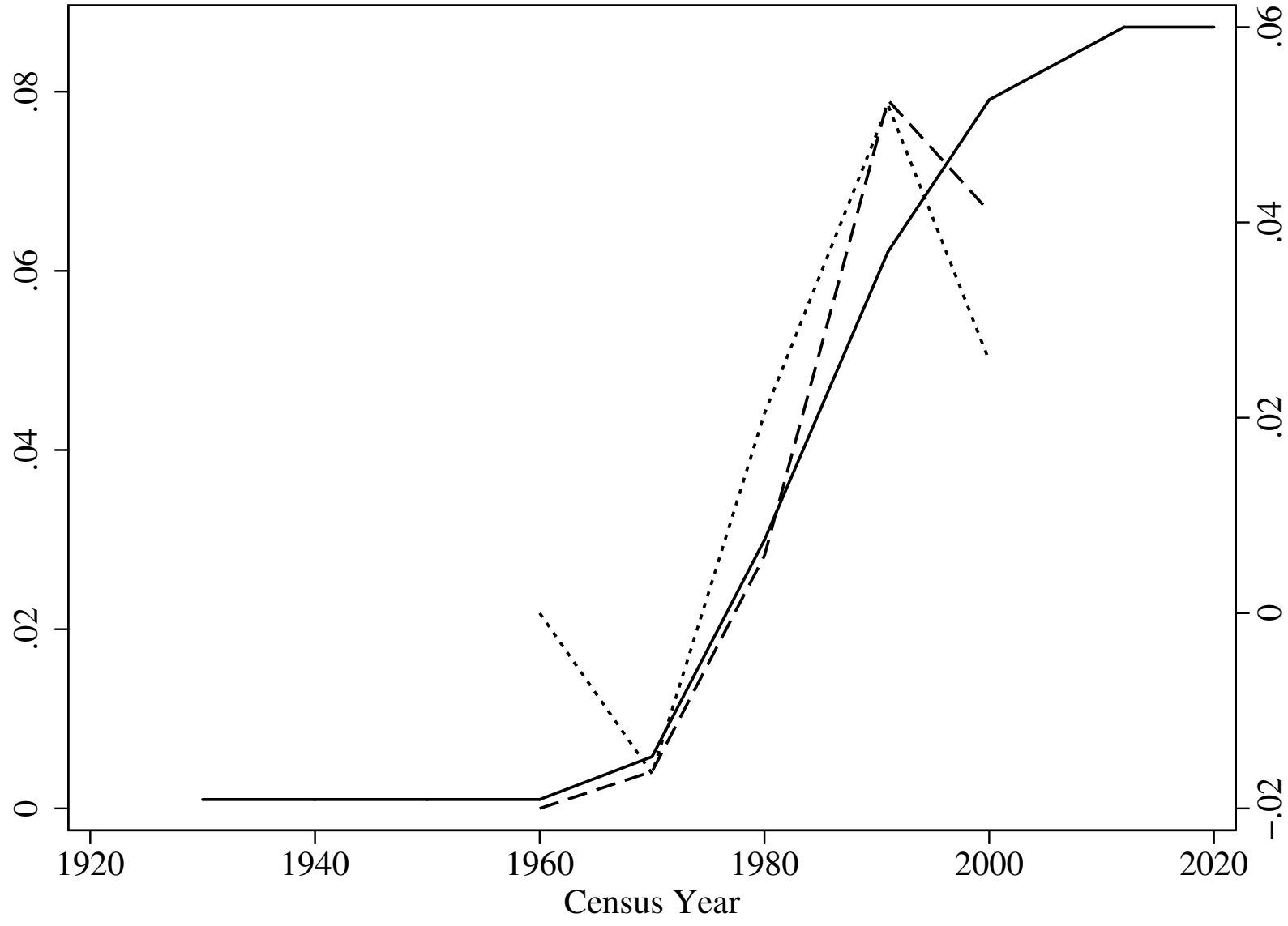

Hookworm, Basic Specification
Hookworm, Expanded Controls
Hookworm, Mitchener−McLean Controls
Malaria, Basic Specification
Malaria, Expanded Controls
Malaria, Mitchener−McLean Controls
1880
1900
1920
1940
1960
1980
2000


Hookworm, Basic Specification
Hookworm, Expanded Controls
Hookworm, Mitchener−McLean Controls
Malaria, Basic Specification
Malaria, Expanded Controls
Malaria, Mitchener−McLean Controls
1880
1900
1920
1940
1960
1980
2000

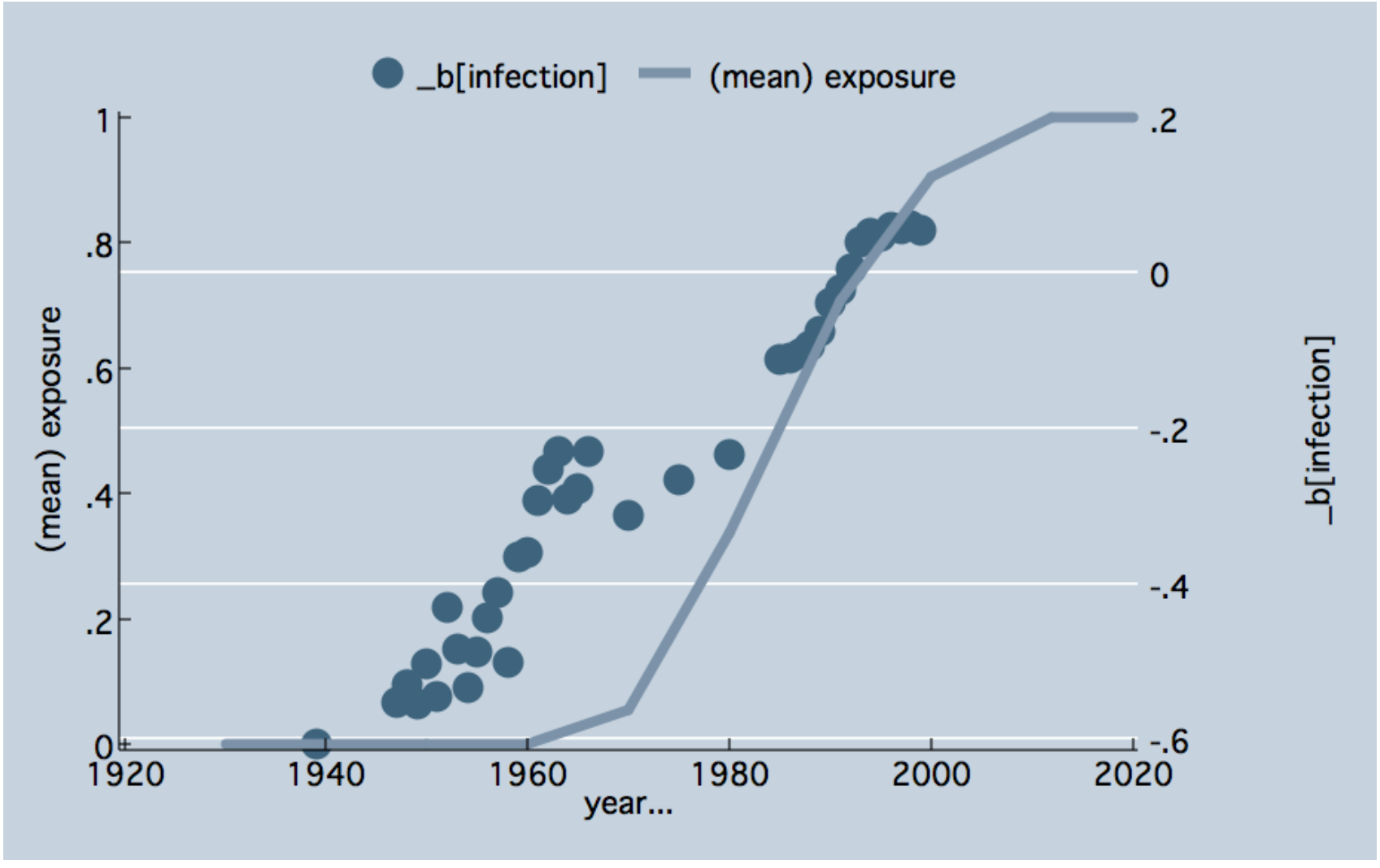

Hookworm, Basic Specification
Hookworm, Expanded Controls
Hookworm, Mitchener−McLean Controls
Malaria, Basic Specification
Malaria, Expanded Controls
Malaria, Mitchener−McLean Controls
1880
1900
1920
1940
1960
1980
2000
−.5
0
.5
1
1.5
−1
1
2
3
4


Hookworm, Basic Specification
Hookworm, Expanded Controls
Hookworm, Mitchener−McLean Controls
Malaria, Basic Specification
Malaria, Expanded Controls
Malaria, Mitchener−McLean Controls
1880
1900
1920
1940
1960
1980
2000

Spillover effects, Brazilian States



# Aggregate effects, Brazilian States



# Interactions among Diseases

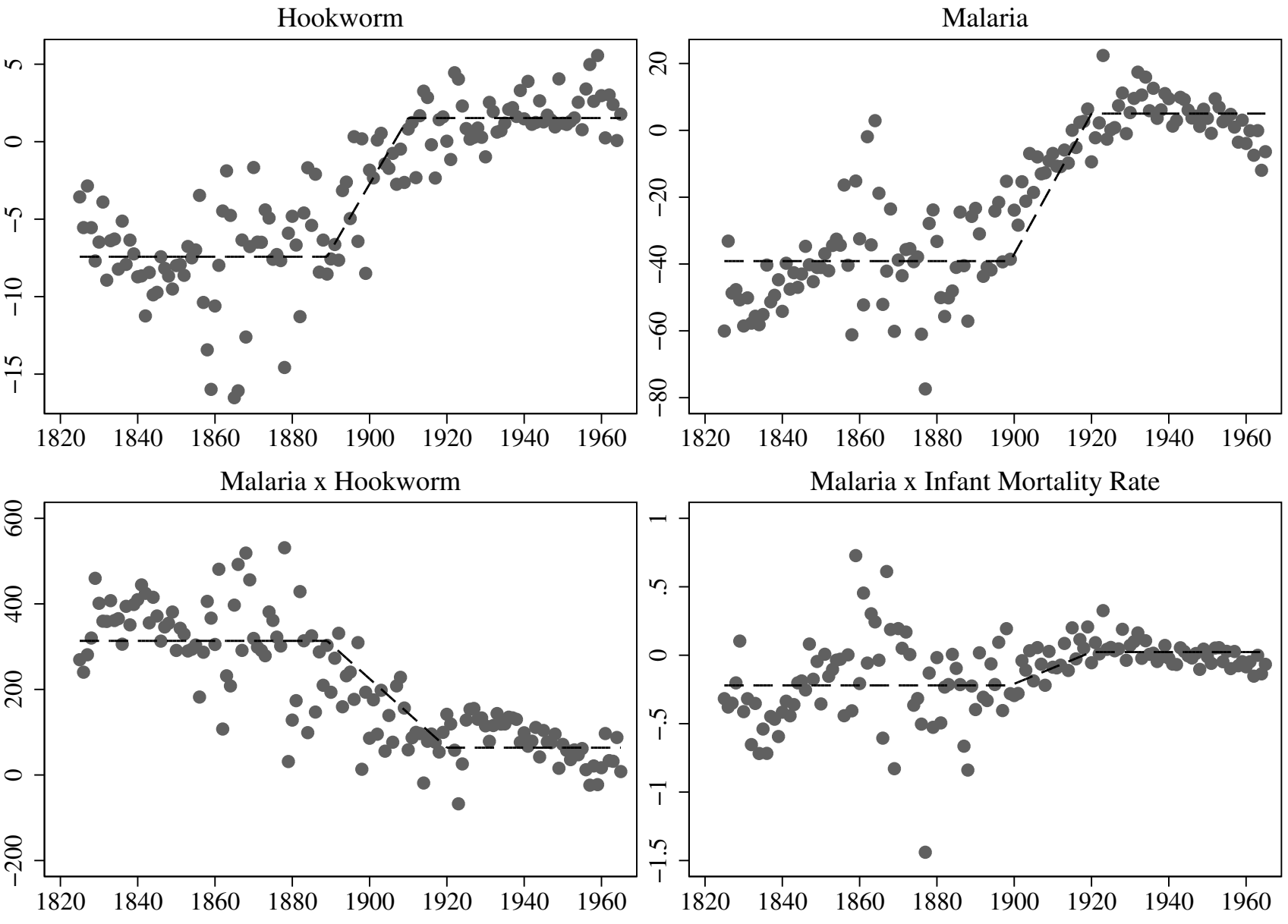
- Does a disease-specific intervention have more or less effect if health along other dimensions is poor?
- Two logical possibilities:
  1. $\frac{\partial^2 Y}{\partial h_1 \partial h_2} > 0$. Co-morbidities reinforce each other.
  2. $\frac{\partial^2 Y}{\partial h_1 \partial h_2} < 0$. Once you're sick, you're sick.

# Estimating Equation 1

For each year of birth $k$:

$$Y_{jk} = \beta_k \, \mathrm{M}_j + \alpha_k \, \mathrm{H}_j + \theta_k \, \mathrm{H}_j \times \mathrm{M}_j + \phi_k \, \mathrm{M}_j \times \mathrm{IMR}_j + \delta_k + X_j \, \Gamma_k + \nu_{jk}$$

# Estimated Interactions



# Falciparum versus Vivax

- Mostly *vivax* in the Americas
- Data on the mix of infections in Colombia circa 1955.
- Weak evidence that it's vivax that generates results above.

# Open questions

- General equilbrium effects
- Interaction effects
- Vivax versus Falciparum
- Related evidence on parasitic disease

# Malaria Eradication in the Americas

## A Retrospective Analysis of Childhood Exposure

Hoyt Bleakley

University of Chicago, Graduate School of Business

March 19, 2008