Disease and Development in the Americas
A Retrospective Analysis of Childhood Exposure To Hookworm and Malaria

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October 2007
Introduction

- Does disease cause underdevelopment in the tropics?
- Measure the effect of health environment!
- Use targeted public-health interventions as ‘leverage’
- Efforts to combat tropical disease in the Americas
  - Hookworm (Southern U.S., circa 1910)
  - Malaria (US South, c 1920; LatAm, c 1957)
- Why childhood exposure?
  - Childhood symptoms/infection worse
  - Childhood as base of investments/development
Why Study These Particular Diseases?

1. Symptoms
2. Still Prevalent in Much of the Tropical Belt
3. Circumstances that lead to the Campaign
   1. Innovations to Knowledge
   2. Innovations to Spending on Public Health
   3. And the origins of both external to the affected regions.
Program for the Talk

1. Hookworm

2. Malaria
   - United States, circa 1920
   - Latin America, late 1950s

3. Discussion
   - Interpretation
   - Extrapolations

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

But almost nobody knew about it!
Rockefeller takes on Hookworm in the South, *circa* 1910.
Rockefeller Campaign: Dispensaries

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Disease and Development in the Americas

Hookworm

Malaria
United States, circa 1920
Latin America, late 1950s

Discussion
Interpretation
Extrapolations

Summary
Disease and Development in the Americas

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Rockefeller Campaign: Education

Hookworm

Malaria

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Latin America, late 1950s

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Summary
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

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Latin America, late 1950s

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Summary
Areas with High Pre-Eradication Hookworm Saw Faster Cross-Cohort Growth in Income.
Childhood Exposure to Eradication Campaign

- Year of birth relative to start of campaign
- Childhood exposure to eradication campaign

- Disease and Development in the Americas
- Hoyt Bleakley

- Hookworm
- Malaria
  - United States, circa 1920
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Childhood Exposure to Eradication Campaign

- Year of birth relative to start of campaign
- Childhood exposure to eradication campaign
- Born after the campaign
Childhood Exposure to Eradication Campaign

- already an adult when the campaign starts
- born after the campaign

- childhood exposure to eradication campaign

year of birth relative to start of campaign
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Childhood Exposure to Eradication Campaign

- already an adult when the campaign starts
- born after the campaign

childhood exposure to eradication campaign

year of birth relative to start of campaign
Childhood Exposure to Eradication Campaign

- already an adult when the campaign starts
- partially exposed
- born after the campaign

childhood exposure to eradication campaign

year of birth relative to start of campaign
Childhood Exposure to Eradication Campaign

- already an adult when the campaign starts
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childhood exposure to eradication campaign

year of birth relative to start of campaign
Childhood Exposure to Eradication Campaign

Design 1: Pre/Post Comparison

year of birth relative to start of campaign

0

already an adult when the campaign starts
partially exposed
born after the campaign

childhood exposure to eradication campaign

1

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Disease and Development in the Americas
Hookworm
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Childhood Exposure to Eradication Campaign

- already an adult when the campaign starts
- partially exposed
- born after the campaign

Design 1: Pre/Post Comparison
Children's Exposure to Eradication Campaign

- Already an adult when the campaign starts
- Partially exposed
- Born after the campaign

Year of birth relative to start of campaign

Design 2: Detailed Cohort Comparison
Childhood Exposure to Eradication Campaign

- already an adult when the campaign starts
- partially exposed
- born after the campaign

childhood exposure to eradication campaign

year of birth relative to start of campaign
When did the changes happen?

Cohort-by-cohort Estimates:

\[ y_{it} = \alpha_t + \beta_t M_i + X_i \Gamma_t + \epsilon_{it} \]

where \( t \) is year of birth and \( i \) is area of birth.

Plot the \( \beta \).

1. Do we observe a shift?
2. When does it happen?
3. Does it coincide with childhood exposure?
The Shift in Income Coincided with Childhood Exposure to Hookworm (the dashed line)
Program for the Talk

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The U.S. Takes an Interest

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Summary
This new knowledge was “repatriated” in the early 1920s.

↓

Large declines in malaria mortality followed.
Areas with Large Malaria Burdens Saw Large Declines in Morbidity.

Are similar patterns evident for other outcomes?

Does it correspond to child exposure?
Childhood Exposure to Eradication Campaign

- already an adult when the campaign starts
- partially exposed
- born after the campaign

childhood exposure to eradication campaign

year of birth relative to start of campaign

-18  0
Program for the Talk

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   - Extrapolations
4. Summary
Malaria Ecology: Colombia
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

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Summary
Cases Notified per 1K Population, Colombia

Discussion
Interpretation
Extrapolations
Summary

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Disease and Development in the Americas
Hookworm
Malaria
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Latin America, late 1950s
Malaria Eradication

- Areas with Large Malaria Burdens Saw Large Declines in Morbidity.
- Are similar patterns evident for other outcomes?
- Does it correspond to child exposure?
Childhood Exposure to Eradication Campaign

- already an adult when the campaign starts
- partially exposed
- born after the campaign

year of birth relative to start of campaign
Brazil, Basic Specification
Mexico, Basic Specification
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

<table>
<thead>
<tr>
<th>Specification:</th>
<th>Outcome:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree of Polynomial-Trend Control:</td>
<td>0</td>
</tr>
<tr>
<td>Degree of Autoregressive Process:</td>
<td>0</td>
</tr>
</tbody>
</table>

#### Panel A: United States

<table>
<thead>
<tr>
<th>Basic</th>
<th>Occupational Income Score</th>
<th>0.124 ***</th>
<th>0.109 ***</th>
<th>0.104 ***</th>
<th>0.094 ***</th>
<th>0.109 ***</th>
<th>0.093 ***</th>
<th>0.082 **</th>
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<td></td>
<td></td>
<td>(0.004)</td>
<td>(0.009)</td>
<td>(0.015)</td>
<td>(0.019)</td>
<td>(0.008)</td>
<td>(0.030)</td>
<td>(0.036)</td>
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<tr>
<td></td>
<td>Additional controls</td>
<td>Occupational Income Score</td>
<td>0.061 ***</td>
<td>0.150 ***</td>
<td>0.128 ***</td>
<td>0.101 ***</td>
<td>0.131 ***</td>
<td>0.120 ***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.006)</td>
<td>(0.012)</td>
<td>(0.011)</td>
<td>(0.026)</td>
<td>(0.011)</td>
<td>(0.027)</td>
<td>(0.047)</td>
</tr>
<tr>
<td></td>
<td>Birthstate x census&gt;1920</td>
<td>Occupational Income Score</td>
<td>0.071 ***</td>
<td>0.150 ***</td>
<td>0.133 ***</td>
<td>0.099 ***</td>
<td>0.131 ***</td>
<td>0.026 **</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.005)</td>
<td>(0.010)</td>
<td>(0.009)</td>
<td>(0.022)</td>
<td>(0.008)</td>
<td>(0.015)</td>
<td>(0.040)</td>
</tr>
<tr>
<td>Basic</td>
<td>Duncan's Index</td>
<td>0.162 ***</td>
<td>0.126 ***</td>
<td>0.138 ***</td>
<td>0.113 ***</td>
<td>0.139 ***</td>
<td>0.121 **</td>
<td>0.114 **</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.007)</td>
<td>(0.015)</td>
<td>(0.022)</td>
<td>(0.031)</td>
<td>(0.014)</td>
<td>(0.050)</td>
<td>(0.060)</td>
</tr>
<tr>
<td></td>
<td>Additional controls</td>
<td>Duncan's Index</td>
<td>0.088 ***</td>
<td>0.184 ***</td>
<td>0.058 ***</td>
<td>0.154 ***</td>
<td>0.172 ***</td>
<td>0.041</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.010)</td>
<td>(0.018)</td>
<td>(0.018)</td>
<td>(0.044)</td>
<td>(0.017)</td>
<td>(0.030)</td>
<td>(0.079)</td>
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<td></td>
<td>Birthstate x census&gt;1920</td>
<td>Duncan's Index</td>
<td>0.099 ***</td>
<td>0.181 ***</td>
<td>0.067 ***</td>
<td>0.159 ***</td>
<td>0.168 ***</td>
<td>0.053 **</td>
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<tr>
<td></td>
<td></td>
<td>(0.007)</td>
<td>(0.014)</td>
<td>(0.012)</td>
<td>(0.031)</td>
<td>(0.013)</td>
<td>(0.023)</td>
<td>(0.063)</td>
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</table>

#### Panel B: Brazil

<table>
<thead>
<tr>
<th>Basic</th>
<th>Log Total Income</th>
<th>0.184 ***</th>
<th>0.220 ***</th>
<th>0.164 ***</th>
<th>0.197 **</th>
<th>0.277 ***</th>
<th>0.122</th>
<th>0.205</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(0.020)</td>
<td>(0.048)</td>
<td>(0.047)</td>
<td>(0.092)</td>
<td>(0.048)</td>
<td>(0.087)</td>
<td>(0.620)</td>
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<td></td>
<td>Additional controls</td>
<td>Log Total Income</td>
<td>0.348 ***</td>
<td>0.437 ***</td>
<td>0.308 ***</td>
<td>0.405 ***</td>
<td>0.486 ***</td>
<td>0.268 *</td>
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<tr>
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<td></td>
<td>(0.019)</td>
<td>(0.050)</td>
<td>(0.082)</td>
<td>(0.128)</td>
<td>(0.048)</td>
<td>(0.160)</td>
<td>(1.896)</td>
</tr>
<tr>
<td></td>
<td>Additional controls</td>
<td>Log Earned Income</td>
<td>0.297 ***</td>
<td>0.459 ***</td>
<td>0.345 ***</td>
<td>0.520 **</td>
<td>0.432 ***</td>
<td>0.308</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.042)</td>
<td>(0.110)</td>
<td>(0.117)</td>
<td>(0.260)</td>
<td>(0.138)</td>
<td>(0.224)</td>
<td>(2.069)</td>
</tr>
<tr>
<td></td>
<td>Additional controls, drop 1960 census</td>
<td>Log Total Income</td>
<td>0.226 ***</td>
<td>0.133 **</td>
<td>0.190 ***</td>
<td>0.088</td>
<td>0.201 ***</td>
<td>0.132</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.023)</td>
<td>(0.061)</td>
<td>(0.058)</td>
<td>(0.120)</td>
<td>(0.055)</td>
<td>(0.125)</td>
<td>(0.714)</td>
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</table>

#### Panel C: Colombia

<table>
<thead>
<tr>
<th>Basic</th>
<th>Occupational Income Score</th>
<th>0.036 **</th>
<th>0.041 **</th>
<th>0.036 ***</th>
<th>0.034 **</th>
<th>0.031 **</th>
<th>0.032 **</th>
<th>0.036 **</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(0.015)</td>
<td>(0.016)</td>
<td>(0.014)</td>
<td>(0.014)</td>
<td>(0.014)</td>
<td>(0.013)</td>
<td>(0.018)</td>
</tr>
<tr>
<td></td>
<td>Additional controls</td>
<td>Occupational Income Score</td>
<td>0.063 ***</td>
<td>0.047 **</td>
<td>0.053 ***</td>
<td>0.025 **</td>
<td>0.032 **</td>
<td>0.037 **</td>
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<tr>
<td></td>
<td></td>
<td>(0.019)</td>
<td>(0.023)</td>
<td>(0.018)</td>
<td>(0.018)</td>
<td>(0.016)</td>
<td>(0.020)</td>
<td>(0.020)</td>
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</tbody>
</table>
Degree of Polynomial-Trend Control: 0 1 0 1 2 0 2
Degree of Autoregressive Process: 0 0 1 1 0 2 2

<table>
<thead>
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<th>Specification:</th>
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<tbody>
<tr>
<td><strong>Panel A: United States</strong></td>
<td></td>
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<tr>
<td>Basic</td>
<td>Occupational Income Score</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional controls</td>
<td>Occupational Income Score</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Birthstate x census&gt;1920</td>
<td>Occupational Income Score</td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td>Basic</td>
<td>Duncan's Index</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional controls</td>
<td>Duncan's Index</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Birthstate x census&gt;1920</td>
<td>Duncan's Index</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Panel B: Brazil</strong></td>
<td></td>
</tr>
<tr>
<td>Basic</td>
<td>Log Total Income</td>
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<tr>
<td></td>
<td></td>
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<tr>
<td>Additional controls</td>
<td>Log Total Income</td>
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<tr>
<td>Additional controls</td>
<td>Log Earned Income</td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional controls, drop 1960 census</td>
<td>Log Total Income</td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td><strong>Panel C: Colombia</strong></td>
<td></td>
</tr>
<tr>
<td>Basic</td>
<td>Industrial Income Score</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional controls</td>
<td>Industrial Income Score</td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Panel D: Mexico</strong></td>
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<tr>
<td>Basic</td>
<td>Log Earned Income</td>
</tr>
<tr>
<td></td>
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<tr>
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<td></td>
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</tr>
<tr>
<td>Additional controls, drop 1960 census</td>
<td>Log Earned Income</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Standard model: \( MB = MC \) of schooling

Childhood malaria depresses both.

Predictions ambiguous about inputs.

To first order, outputs \( \uparrow \).
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

- already an adult when the campaign starts
- partially exposed
- born after the campaign

Design 1: Pre/Post Comparison
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 ↑
- Similar results: movers and nonmovers
- Similar results in US for mother’s BPL
Program for the Talk

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Interpretation: Reduced-form Income Differences

Compare most malarious to least malarious areas.

- United States (occscore): 0.13
- United States (Duncan): 0.16
- Brazil (total): 0.37
- Brazil (earned): 0.26
- Mexico (earned): 0.24
- Colombia (indscore): 0.39
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” \( \Delta m \approx 0.6 \)
Effect per probability of childhood infection?

Normalize the reduced-form differences with the estimated decline in malaria

- US: $\Delta y/\Delta m = 0.145/0.3 \approx 0.47$
- Brazil: $\Delta y/\Delta m = 0.37/0.625 \approx 0.59$
- Mexico: $\Delta y/\Delta m = 0.26/0.625 \approx 0.41$
- Colombia: $\Delta y/\Delta m = 0.07/0.625 \approx 0.11$ (adjusted: 0.39)
<table>
<thead>
<tr>
<th>Dependent Variables:</th>
<th>United States</th>
<th>Brazil</th>
<th>Colombia</th>
<th>Mexico</th>
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</thead>
<tbody>
<tr>
<td>Occupational Income Score</td>
<td>0.14</td>
<td>0.37</td>
<td>0.28 (adjusted)</td>
<td>0.26</td>
</tr>
<tr>
<td>Duncan's Index</td>
<td>0.18</td>
<td>0.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log Total Income</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log Earned Income</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduced-form Differences; 95/5 percentile comparison</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mesoendemic (0.3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximal Endemicity (approx. Malaria Infection Rate)</td>
<td></td>
<td>Hyperendemic (0.625)</td>
<td>Hyperendemic (0.625)</td>
<td>Hyperendemic (0.625)</td>
</tr>
<tr>
<td>Income Effect per Probability of Childhood Infection</td>
<td>0.47</td>
<td>0.59</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>0.60</td>
<td>0.45</td>
<td>0.41</td>
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</table>
Program for the Talk

1. Hookworm

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Regional comparisons

Between North and South (US):
- 1900 gap in log(GDP) was 0.75
- 10–20% infection ; effect of 0.6 on income
- ⇒ 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
- → 10-16% of the gap
Comparison with macro estimates

- Me: $\frac{\partial \log Y}{\partial \text{Prob(infection)}} \approx -0.6$

- Sachs & co.: $\frac{\partial \log Y}{\partial \text{Prob(infection)}} \approx -2.15$

- About 25% of the macro estimate.

- But note about *falciparum*
Summary

- Rockefeller campaign against hookworm, circa 1910
- Large drop in malaria, circa 1920 in the US South and circa 1950 in LatAm
- Resulted from external factors
- Nonmalarious areas serve as a comparison group
- Faster cross-cohort income growth in treated areas
- Coincident with childhood exposure to the program
- Large effect on adult income of childhood exposure
Background papers


http://www.mitpressjournals.org/doi/abs/10.1162/qjec.121.1.73

http://research.chicagogsb.edu/economy/research/articles/205.pdf


http://home.uchicago.edu/~bleakley/Bleakley_Malaria_August2007.pdf


(Links to these papers also at the author’s home page: http://home.uchicago.edu/~bleakley.)
Open questions

- General equilibrium effects
- Interaction effects
- Malaria: Vivax versus Falciparum
Disease and Development in the Americas
A Retrospective Analysis of Childhood Exposure To Hookworm and Malaria

Hoyt Bleakley

University of Chicago, Graduate School of Business

October 2007