**THE SOCIAL COST OF LEAD: EFFECTS ON ACADEMIC PERFORMANCE AND BEHAVIOR**

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Boston Office of Fair Housing and Equity  
October 22, 2014

**MOTIVATION**

- Individual people make up a society, and seemingly small influences on who those people are and how they behave can have a large influence on the society as a whole.
- Lead is a toxin with far-reaching effects.
- What do these effects add up to at the societal level? What do they mean for Boston?

**THE THOUGHT EXPERIMENT**

Consider a single birth cohort: all individuals born in the United States in the year 2010. What would their lives look like in...

- **a Leaded World?**
  - Cohort has the actual lead distribution
  - As a consequence, they are adversely affected in a variety of ways
  - There are cognitive, behavioral, health, and other effects throughout their lives
  - Social cost of lead = present discounted value of the costs of these effects

- **an Unleaded World?**
  - Everyone has lead level close to zero, or < 1 μg/dl
  - They therefore suffer no ill effects from lead
  - Social costs of lead are zero

**Effects of Lead**

- Cognitive
  - IQ, earnings, tax revenue
  - Special Education, ADHD

- Behavioral
  - Social Behavior: Crime, Juvenile Delinquency, Teen Pregnancy
  - Other: Smoking, Child abuse, poverty, “soft skills”

- Health
  - Fetal & Infant: Fetal Mortality, Low Birthweight
  - Childhood: Direct treatment of lead poisoning, other health effects
  - Adult: Respiratory, Cardiovascular, Renal

- Other
  - Welfare, social programs
  - Lead-reduction policy infrastructure, Criminal justice infrastructure

**EXISTING LITERATURE**

EARLY LIFE INFLUENCES

Growing literature in economics investigating the importance of early life influences

- "Schools, Skills and Synapses" – Heckman (2008)
  - "Many major economic and social problems such as crime, teenage pregnancy, dropping out of high school and adverse health conditions are linked to low levels of skill and ability in society."
  - Both cognitive and socioemotional skills are important
  - Early intervention can be effective
  - "Recent research establishes the power of socioemotional abilities and an important role for environment and intervention in creating abilities... inequality can be attacked at its source."

COGNITIVE

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>IQ &amp; Earnings</th>
<th>Special Education</th>
<th>ADHD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead → IQ</td>
<td>Lead → IQ</td>
<td>Lead more children with IQ &lt; 70</td>
<td>Lead → ADHD</td>
</tr>
<tr>
<td>Lead shifts the IQ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>distribution to the left</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>@oz et al (2010)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Only medical costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead increases impulsivity</td>
<td>Cost of $135k per child, incurred for 0.47% of cohort (20,000 children)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>inattention, hyperactivity</td>
<td>Medical cost of $7k per child, incurred for 24,187 children</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cost per cohort $28.08 billion $1.04 billion $174 million

LEAD AND IQ

IQ Distributions under Various Lead Scenarios

DETAIL of Lower Portion of IQ Distribution under Various Lead Scenarios

MASSACHUSETTS LEAD 1990-2009

RATE OF LEAD ABOVE 10 MCG/DL

Rate of Blood Lead > 10 mcg/dl
MA Children by Birth Year (1990–2009)

Density

Blood Lead (mcg/dl)

Notes: Average over all children measured for lead in Massachusetts 1990 to 2009.
Data from Childhood Lead Poisoning Prevention Program of the Massachusetts Department of Public Health.
Towns sorted into income categories based on per-capita income in the year 2000.
Low is bottom quartile (<$20k), Medium is middle two quartiles ($20k-30k), High is top quartile ($30k+).

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Notes: Author’s calculations on individual MA CLPPP data, screened children.
By Income Category and Birth Year

Massachusetts Childhood Blood Lead Distributions


Notes: Author’s calculations on individual MA CLPPP data, screened children. Per-capita town income categories: Low < $20k, Medium $20k-30k, High $30k+

Massachusetts MCAS Math Score Distributions


Notes: Author’s calculations on individual MA DOE data.

By Birth Year

Massachusetts MCAS Math Score Distributions


Notes: Author’s calculations on individual MA DOE data.

MCAS MATH VS. LEAD

Notes: Author’s calculations as described in text.
MCAS Score is the group average percent correct.
Childhood Lead is the group average in mcg/dl.

For Fourth Grade, by Birth Year

Figure 2a. MCAS English Score vs. Childhood Lead


MCAS ELA VS. LEAD

Notes: Author’s calculations as described in text.
MCAS Score is the group average percent correct.
Childhood Lead is the group average in mcg/dl.

For Fourth Grade, by Birth Year

Figure 2b. MCAS Math Score vs. Childhood Lead


DIFFERENCES IN DIFFERENCES

Table 2. Differences-in-Differences.

<table>
<thead>
<tr>
<th>Outcome Measure</th>
<th>DD1</th>
<th>DD2</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCAS Score 95th</td>
<td>0.006</td>
<td>0.009</td>
</tr>
<tr>
<td>90th</td>
<td>0.012</td>
<td>0.012</td>
</tr>
<tr>
<td>80th</td>
<td>0.017</td>
<td>0.018</td>
</tr>
<tr>
<td>70th</td>
<td>0.022</td>
<td>0.022</td>
</tr>
</tbody>
</table>

large decreases in lead
→ larger improvements in MCAS performance
EXTRAPOLATING FOR MA CHILDREN BORN AFTER YEAR 2000...

Actual Lead Levels and Predicted MICAS Scores for Birth Cohorts 2000 to 2009

High Income

Low Income

Medium Income

Lowest


LEAD & ACADEMIC PERFORMANCE

- Policy: Massachusetts has been a leader in implementing public policy to reduce childhood lead exposure
- Results: policy-induced reductions in early childhood lead exposure have significantly affected academic performance in Massachusetts


BEHAVIORAL

<table>
<thead>
<tr>
<th>Crime</th>
<th>Juvenile Delinquency</th>
<th>Teen Pregnancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanism</td>
<td>Lead → behavior → crime</td>
<td>Lead → behavior → delinquency</td>
</tr>
<tr>
<td>Calculation</td>
<td>Lead-related crimes: 500k violent x $200k cost per crime; 4m property x $6k cost per crime</td>
<td>Lead-related delinquency: 67k juvenile delinquency x $21k cost of confinement</td>
</tr>
<tr>
<td>Cost per cohort</td>
<td>$46.0 billion</td>
<td>$1.43 billion</td>
</tr>
</tbody>
</table>

TEEN PREGNANCY VS. BLOOD LEAD

Calculated Cost

1 mcg/dl of blood lead has the same effect as $5,000 of family income

**LEAD & BEHAVIOR**

- Early childhood lead exposure appears to have large negative consequences on behavior:
  - By increasing impulsivity and aggression, even moderate exposure can have substantial adverse effects on behavior.
  - These effects persist, from childhood through young adulthood.

- Prior to the removal of lead from gasoline, the entire U.S. population experienced these levels of moderate exposure:
  - Changes in lead exposure induced by environmental policy could be responsible for societal trends in a wide array of behavioral outcomes.

**EVEN A LITTLE LEAD IS UNAMBIGUOUSLY BAD**

- Twenty years of research shows that lead has **unambiguous** and **long-lasting** effects on intelligence, behavior, and health.

- The research establishes causality: lead **causes** these bad outcomes.

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**TEEN RISKY BEHAVIOR**

<table>
<thead>
<tr>
<th></th>
<th>Electricity (N=1379)</th>
<th>Electricity (N=1365)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex and Pregnancy</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prisoner by age 15</td>
<td>1.061***</td>
<td>1.574***</td>
</tr>
<tr>
<td></td>
<td>(0.416)</td>
<td>(0.472)</td>
</tr>
<tr>
<td>Prisoner by age 19</td>
<td>0.132***</td>
<td>0.486***</td>
</tr>
<tr>
<td></td>
<td>(0.300)</td>
<td>(0.315)</td>
</tr>
<tr>
<td>Got pregnant by age 19</td>
<td>-0.044***</td>
<td>-0.171***</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.025)</td>
</tr>
<tr>
<td>Substance Use:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcohol by age 15</td>
<td>0.036**</td>
<td>0.055**</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Cigarette by age 15</td>
<td>0.007</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Marijuana by age 15</td>
<td>0.004***</td>
<td>-0.016***</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.000)</td>
</tr>
</tbody>
</table>

**EXPECTED COSTS PER CHILD**

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Fetal and Infant Health</th>
<th>Childhood Health</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Details</td>
<td>Infertility, stillbirth, death, low birthweight, small for gestational age, lead poisoning</td>
<td>ADHD, violence, death, service system, undertaker, system, renal</td>
<td>Minuke (2006)</td>
</tr>
<tr>
<td>Calculation</td>
<td>Literature is too minimal</td>
<td>Literature is too minimal</td>
<td>Lead increases probability of disease by 0.2-0.9 percentage points x QALY 0.8-0.9 x $5m value of life, $15k health value lost per person</td>
</tr>
</tbody>
</table>

**Total cost per child from increasing blood lead by 1 mcg/dl ≈ $50,000**

ACKNOWLEDGEMENTS

- Many individuals in Boston (and elsewhere) have supported this research...
- Childhood Lead Poisoning Prevention Program, Bureau of Environmental Health, Massachusetts Department of Public Health: Paul Hunter, Robert Rauter, Sarah Neslund.
- Massachusetts Department of Elementary and Secondary Education: Carrie Conaway, Sarah Carleton.
- Coalition to Prevent Lead Poisoning in Rochester, New York: Katrina Korfmacher, Elizabeth McDade.
- The New England Public Policy Center of the Federal Reserve Bank of Boston: Yolanda Kodrzycki, Alicia Basner Moulliet, Chris Fento, Bo Zhan. A portion of this research was generously supported by the New England Public Policy Center of the Federal Reserve Bank of Boston. The views expressed are those of the author and not necessarily those of the Federal Reserve System or the Federal Reserve Bank of Boston.
- Various other colleagues at Amherst College and elsewhere, including Jun Ishii, Rene Reyes, and Katharine Snee.