The Social Cost of Lead:

Effects on Academic Performance and Behavior

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Childhood Lead Exposure & Housing Discrimination in Boston
Boston Office of Fair Housing and Equity
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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?	*an Unleaded World?*
Cohort has the actual lead distribution	Everyone has lead level close to zero, or < 1 μg/dl
As a consequence, they are adversely affected in a variety of ways	They therefore suffer no ill effects from lead
There are cognitive, behavioral, health, and other effects throughout their lives	Social costs of lead are zero
Social cost of lead = present discounted value of the costs of these effects	

Source: Jessica W. Reyes, "Social Cost of Lead," in "Lead: The Global Poison -- Humans, Animals, and the Environment," a Symposium at the Annual Meeting of the American Association for the Advancement of Science Conference in Boston, MA, February 2013.

Effects of Lead

Cognitive		Behavioral		Health			Other	
IQ, earnings, tax revenue	Special Education, ADHD	Social Behavior: Crime, Juv. Delinq, Teen Pregnancy	Other: Smoking, Child abuse, poverty, "soft skills"	Fetal & Infant: Fetal Mortality, Low Birthweight	Childhood: Direct treatment of lead poisoning, other health effects	Adult: Respiratory, Cardiovasc., Renal	Welfare, social programs	Lead-reduction policy infrastructure, Criminal justice infrastructure

Existing Literature

- **Gould, E. (2009).** "Childhood lead poisoning: conservative estimates of the social and economic benefits of lead hazard control." *Environ Health Perspect* 117(7): 1162-1167.
- **Muennig, P. (2009).** "The social costs of childhood lead exposure in the post-lead regulation era." *Arch Pediatr Adolesc Med* 163(9): 844-849.
- **Korfmacher, K. S. (2003).** "Long-term costs of lead poisoning: How much can New York save by stopping lead?" Environmental Health Sciences Center, University of Rochester, unpublished manuscript.
- **Landrigan, P. J., C. B. Schechter, et al. (2002).** "Environmental pollutants and disease in American children: estimates of morbidity, mortality, and costs for lead poisoning, asthma, cancer, and developmental disabilities." *Environ Health Perspect* 110(7): 721-728.
- **Grosse, S. D., T. D. Matte, et al. (2002).** "Economic gains resulting from the reduction in children's exposure to lead in the United States." *Environ Health Perspect* 110(6): 563-569.
- **Schwartz, J. (1994).** "Societal benefits of reducing lead exposure." *Environ Res* 66(1): 105-124.

Studies on Social Costs of Lead

	Cognitive		Behavioral		Health			Other	
	IQ, earnings, tax revenue	Special Education, ADHD	Social Behavior: Crime, Juv Delinq, Teen Preg.	Other: Smoking, Child abuse, poverty, "soft skills"	Fetal & Infant: Fetal Mortality, Low Birthweight	Child: Direct treatment of lead poisoning, other health effects	Adult: Respiratory, Cardiovasc., Renal	Welfare, social programs	Lead-reduction policy infrastructure, Criminal justice infrastructure
Reyes	Yes	Yes	Yes	No	No	No	Yes	No	No
Gould	Yes	Yes	Some	No	No	Some	No	No	No
Muennig	Yes	Yes	Some	No	No	No	Yes	Some	No
Korfmacher	Yes	Yes	Some	No	No	Some	No	No	Some
Landrigan	Yes	No	No	No	No	No	No	No	No
Grosse	Yes	No	No	No	No	No	No	No	No
Schwartz	Yes	Yes	No	No	Some	Some	Yes	No	No

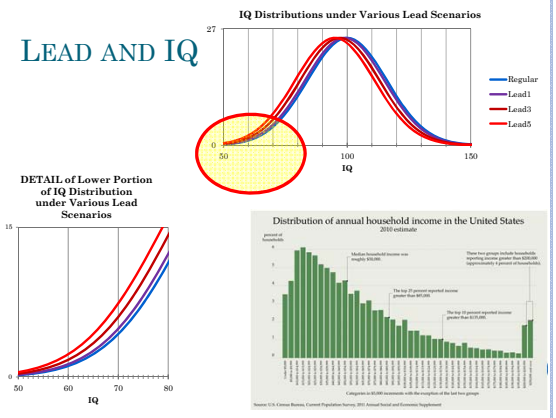
Early Life Influences

- 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

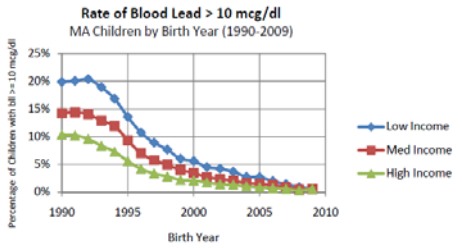
	IQ & Earnings	Special Education	ADHD
Mechanism	Lead → IQ → Earnings	Lead → IQ → more children with IQ < 70	Lead → ADHD
Details	Includes various effects of IQ (HS grad, labor mkt attachment) Canfield et al (2003) Jones et al (2010)	Lead shifts the IQ distribution to the left. Canfield et al. (2003) Parrish (2000)	Only medical costs. Lead increases impulsivity, innattention, hyperactivity. Braun (2006) Ray (2006)
Calculation	Mean loss of 1 IQ pt per child = loss of 1% of lifetime earnings = $7k per child, add up for entire cohort (4.2m)	Cost of $53k per child, incurred for 0.47% of cohort (20,000 children)	Medical cost of $7k per child, incurred for 24,167 children
Cost per cohort	**$28.08 billion**	**$1.04 billion**	**$174 million**

Lead and IQ



Massachusetts Lead 1990-2009

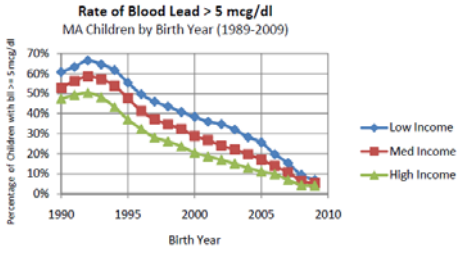
Rate of Lead Above 10 mcg/dL



Notes: Average over all children measured for lead in Massachusetts 1985 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).

Massachusetts Lead 1990-2009

*Rate of Lead Above **5** mcg/dL*



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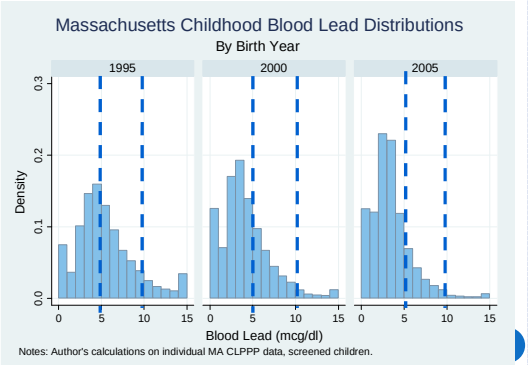
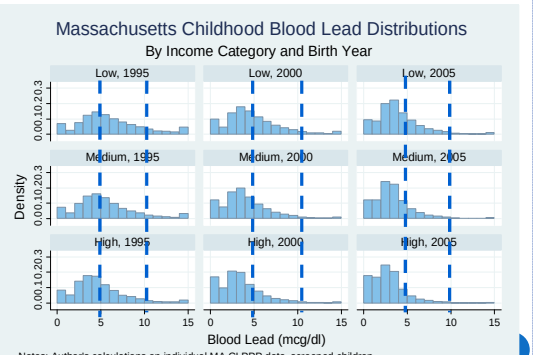


Notes: Author's calculations on individual MA CLPPP data, screened children.

Source: Jessica W. Reyes. "Lead Policy and Academic Performance: Insights from Massachusetts," Harvard Educational Review, forthcoming Winter 2014-2015.



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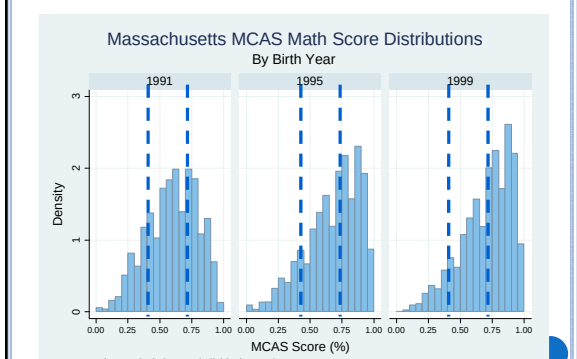

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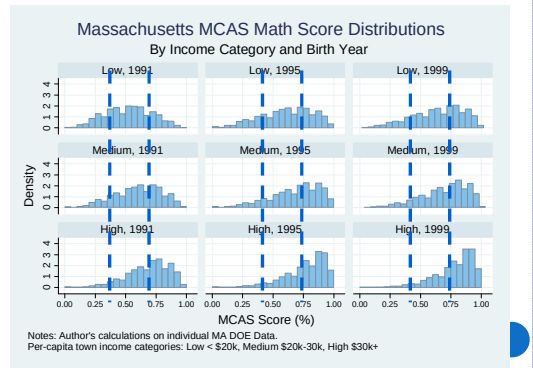

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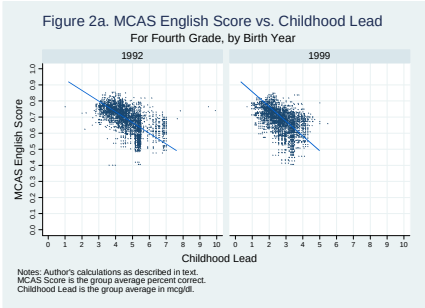
MCAS ELA vs. Lead



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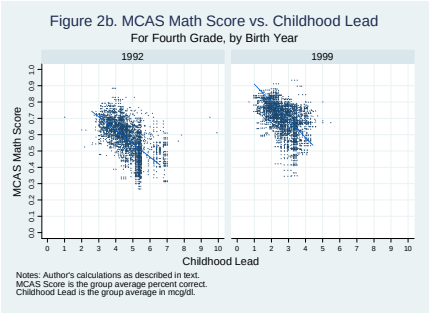
MCAS Math vs. Lead



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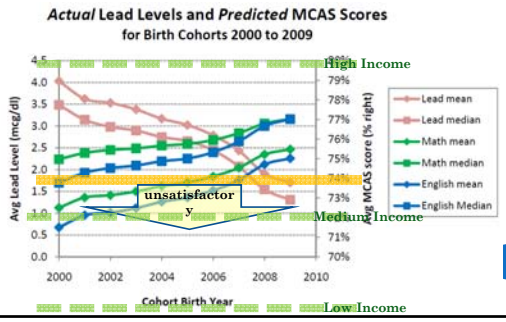
Differences in Differences

Table 2. Differences-in-Differences.

Outcome Measure	*DD1* [a,b]	*DD2* [a,c]
Mean score on MCAS		
3rd grade English	0.016 ** (0.007)	0.029 ** (0.010)
4th grade English	0.009 (0.006)	0.010 (0.009)
4th grade Math	0.031 ** (0.008)	0.045 ** (0.124)
Share Unsatisfactory on MCAS		
3rd grade English	-0.022 (0.016)	-0.052 ** (0.022)
4th grade English	-0.025 (0.017)	-0.038 (0.027)
4th grade Math	-0.047 ** (0.016)	-0.065 ** (0.027)

larger decreases in **lead**
→ larger improvements in **MCAS** performance

Extrapolating for MA children born after year 2000…



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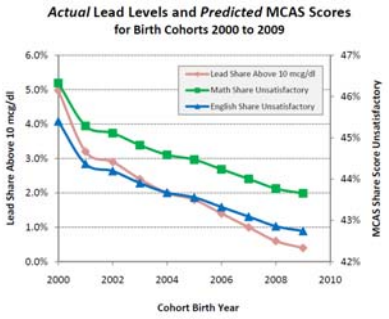


Lead & Academic Performance

- 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

Source: Jessica W. Reyes. "Lead Policy and Academic Performance: Insights from Massachusetts," Harvard Educational Review, forthcoming Winter 2014-2015.

Behavioral

	Crime	Juvenile Delinquency	Teen Pregnancy
Mechanism	Lead → behavior → crime	Lead → behavior → delinquency	Lead → impulsivity → teen preg
Details	Includes monetary and quality of life costs. Reyes (2007) Reyes (2012) FBI UCR (2011) Heaton (2010)	Includes only cost of confinement. Reyes (2012) for Lead → Delinq OJDP (2006) for rates and costs	Includes direct and indirect costs of teen pregnancy. Reyes (2012) Monea & Thomas (2011) Counting it Up (2011)
Calculation	Lead-related crimes: 500k violent x $200k cost per crime; 4m property x $6k cost per crime	Lead-related delinquency: 67k juv delinq x $21k cost of confinement.	Lead-related teen pregnancy: 206k preg x $24k addl costs per preg
Cost per cohort	**$46.0 billion**	**$1.43 billion**	**$4.94 billion**

Lead increases Behavior Problems

	Age 4-12
Total	0.117 ** (0.038)
Oppositional	0.132 ** (0.052)
Antisocial	0.130 * (0.072)
Hyperactive	0.109 ** (0.050)
Headstrong	0.128 ** (0.051)
Behavioral/Emotional Problems	0.259 ** (0.128)

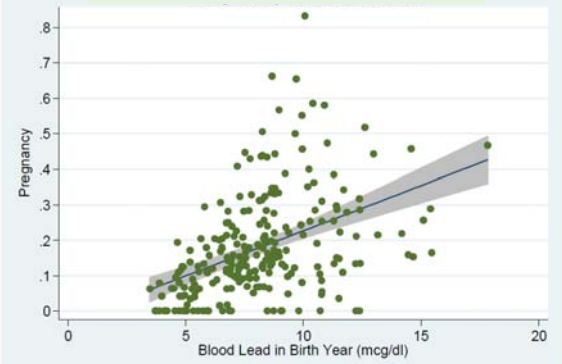
Increase lead by 10% → Increase behavior problems by 1%

Reducing lead from 10 mcg/dl to 5 mcg/dl would reduce behavior problems by 5%

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

Jessica W. Reyes. "Lead Exposure and Behavior: Effects on Aggression and Risky Behavior among Children and Adolescents," NBER Working Paper No. 20366, August 2014.

Teen Pregnancy vs. Blood Lead



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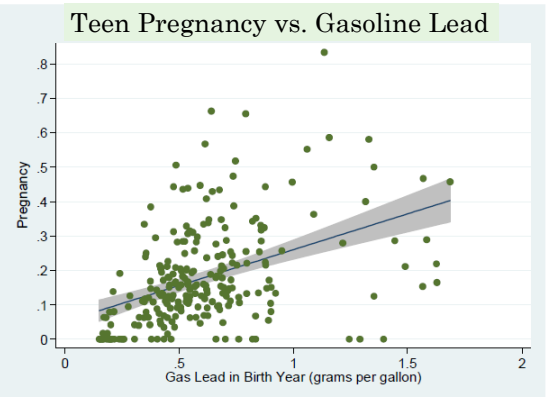

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Teen Risky Behavior

	Elasticity (NLSY79)	Elasticity (NLSY97)
Sex and Pregnancy		
Had sex by age 13		4.276 ** (0.414)
Pregnant by age 17	1.041 ** (0.559)	0.635 ** (0.243)
Pregnant by age 19	1.142 ** (0.440)	0.600 ** (0.151)
Got partner pregnant by age 19		1.736 ** (0.552)
Substance Use		
Alcohol by age 13	0.556 ** (0.190)	0.221 ** (0.088)
Cigarettes by age 13	0.257 (0.195)	0.259 ** (0.082)
Marijuana by age 17	0.568 ** (0.161)	0.050 (0.051)

Δ lead =10 → doubles likelihood of teen pregnancy

Jessica W. Reyes. "Lead Exposure and Behavior: Effects on Aggression and Risky Behavior

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

Jessica W. Reyes. "Lead Exposure and Behavior: Effects on Aggression and Risky Behavior among Children and Adolescents," NBER Working Paper No. 20366, August 2014.

Health

	Fetal and Infant Health	Childhood Health	Adult
Mechanism			
Details	Infertility, fetal death, low birthweight, small for gestational age Silbergeld	ADHD, Seizures, death, nervous system, endocrine system, renal	Menke (2006) Include: myocard & stroke mortality, hypertens, peripharter disease; chronic kidney disease; osteoporosis. Tengs/Wallace (2000) for QALYs
Calculation	Literature is too mixed	Literature is too mixed	Lead increases probability of disease by 0.2-0.8 percentage points x QALY 0.8-0.95 x $5m value of life, → $15k health value lost per person
Cost per cohort	--	--	**$126.9 billion**

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.

Expected Costs per Child

Cognitive $7,503	IQ & Earnings **$7,195**	Special Educ. $266	ADHD $44
Behavioral **$13,418**	Crime **$11,779**	Juv. Delinq. $366	Teen Preg $1,265
Health $32,494	Fetal / Infant --	Child --	Adult **$32,494**

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

Source: Jessica W. Reyes, "Social Cost of Lead," in "Lead: The Global Poison -- Humans, Animals, and the Environment," a Symposium at the Annual Meeting of the American Association for the Advancement of Science Conference in Boston, MA, February 2013.

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