Lead Exposure and Academic Performance in Massachusetts

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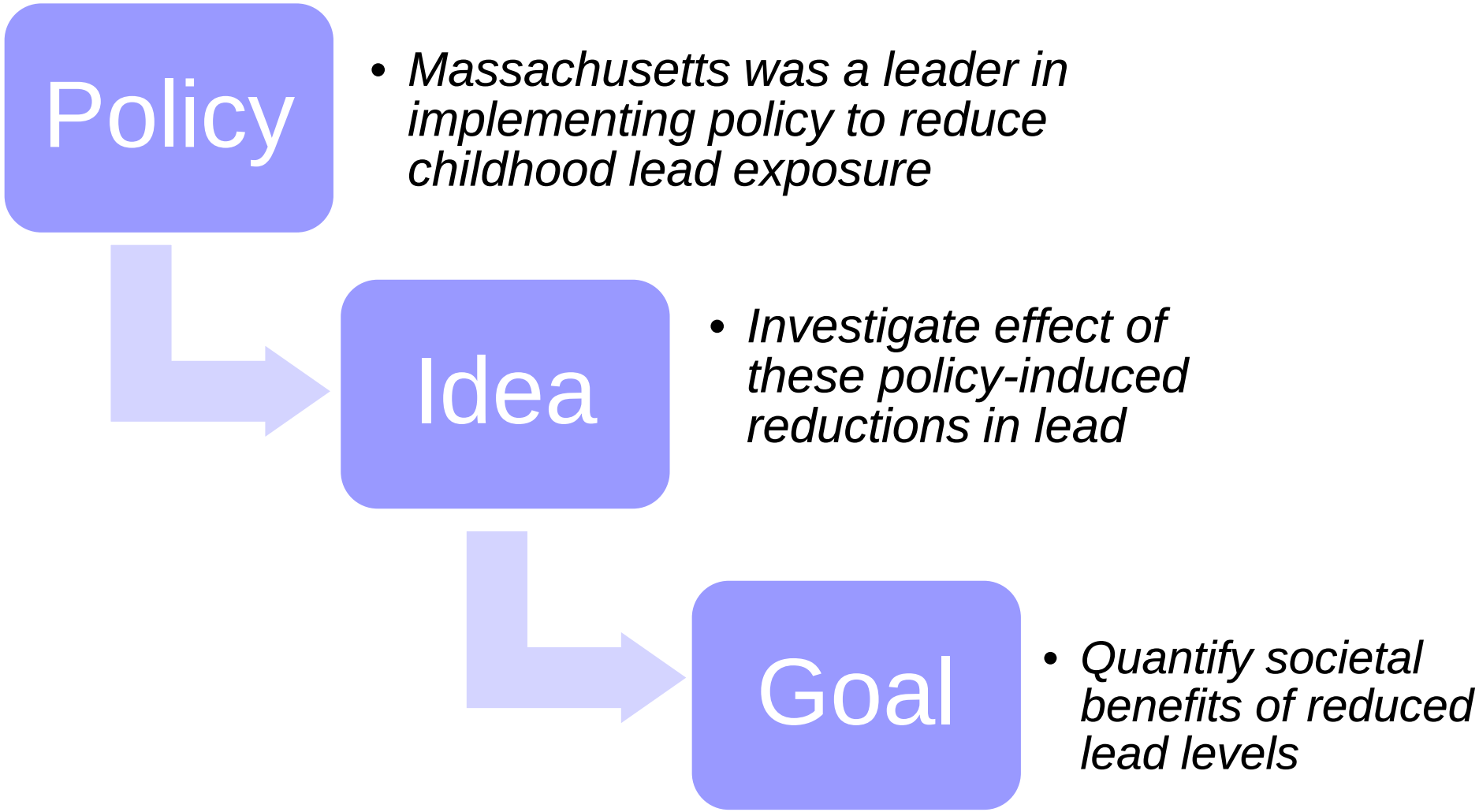
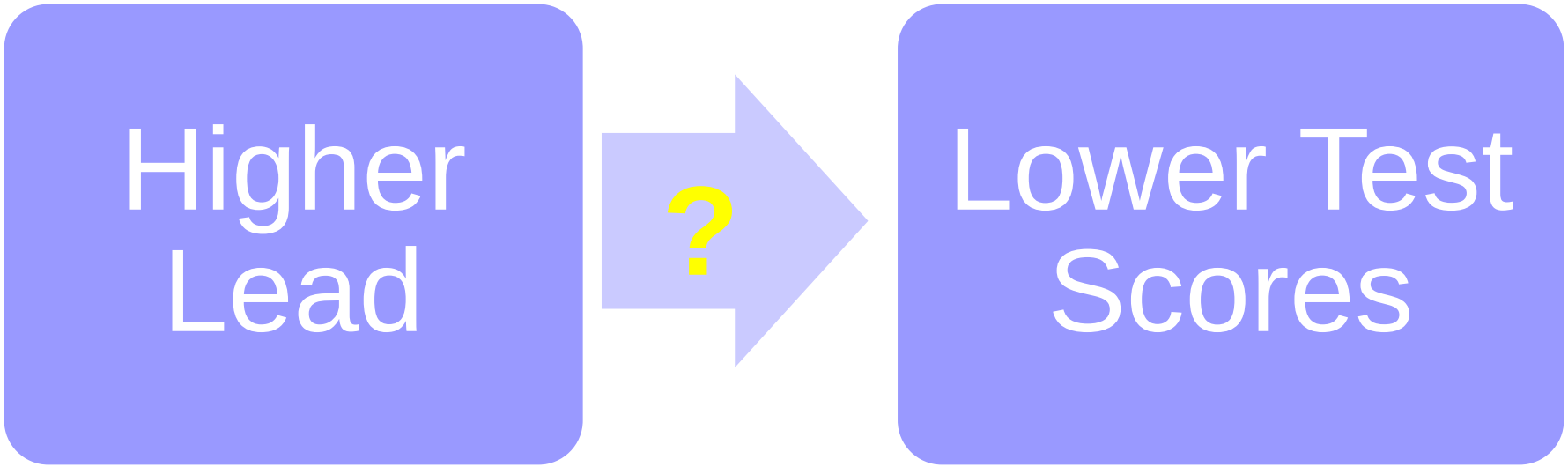
Visiting Scholar at the New England Public Policy Center of the Federal Reserve Bank of Boston.

Motivation

- Children are exposed to numerous environmental toxicants which have plausibly large effects on psychological development, academic performance, and later-life outcomes
- Can improving early life conditions be an effective way to reduce inequality?


Policy
• Massachusetts was a leader in implementing policy to reduce childhood lead exposure
Idea
• Investigate effect of these policy-induced reductions in lead
Goal
• Quantify societal benefits of reduced lead levels

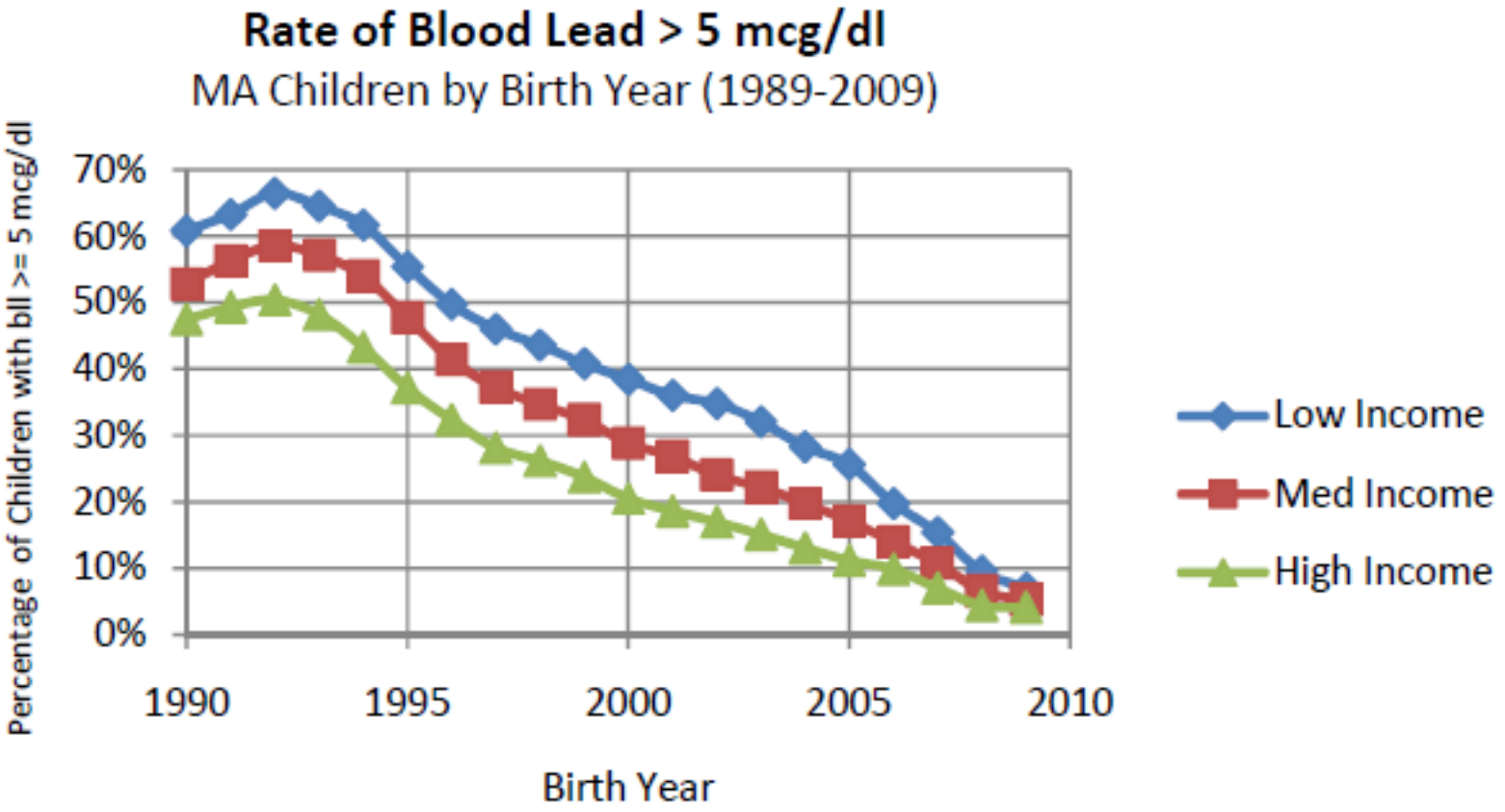

Higher Lead
?
Lower Test Scores

Data

	Lead	Education
Source:	Massachusetts Department of Public Health	Massachusetts Department of Elementary and Secondary Education
Individual-level sample:	MA children sampled for lead	MA children in public schools who took MCAS tests
Groups defined by:	district / school / birth cohort	district / school / birth cohort
Characterization of Distribution	Childhood lead distribution of the group (mean, median, percentiles, share above 10 mcg/dl, etc.)	MCAS score distribution of the group (mean, median, percentiles, share unsatisfactory, etc.)
Years of data:	Lead test years 1988 to 2009 Birth years 1985 to 2009	MCAS test years 2001 to 2009 Birth years 1991 to 2000

Massachusetts Lead

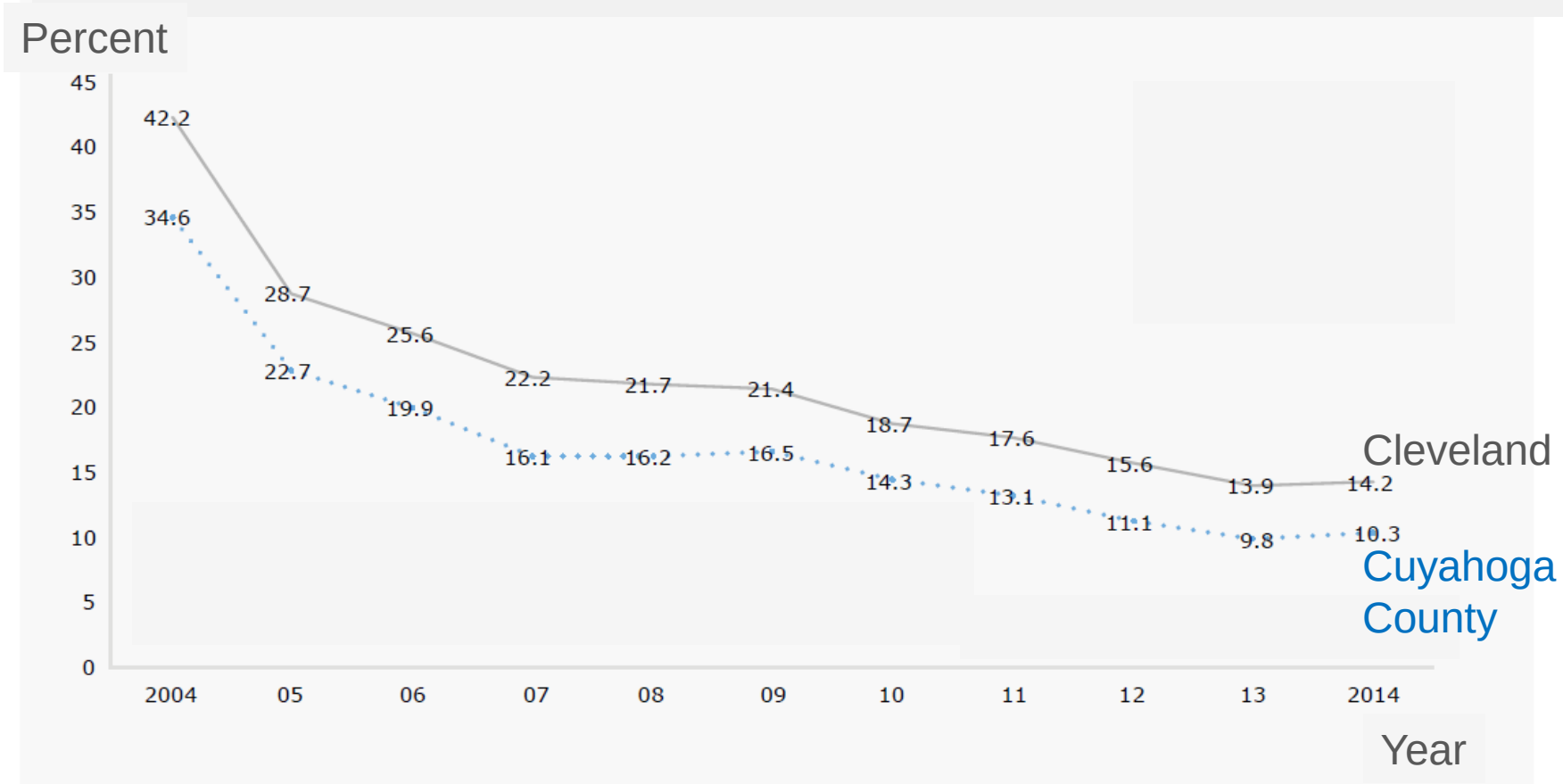
1990-2009 *Rate of lead above 5 mcg/dl*



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).

Cleveland & Cuyahoga County Lead

2004-2014 *Rate of lead above 5 mcg/dl*

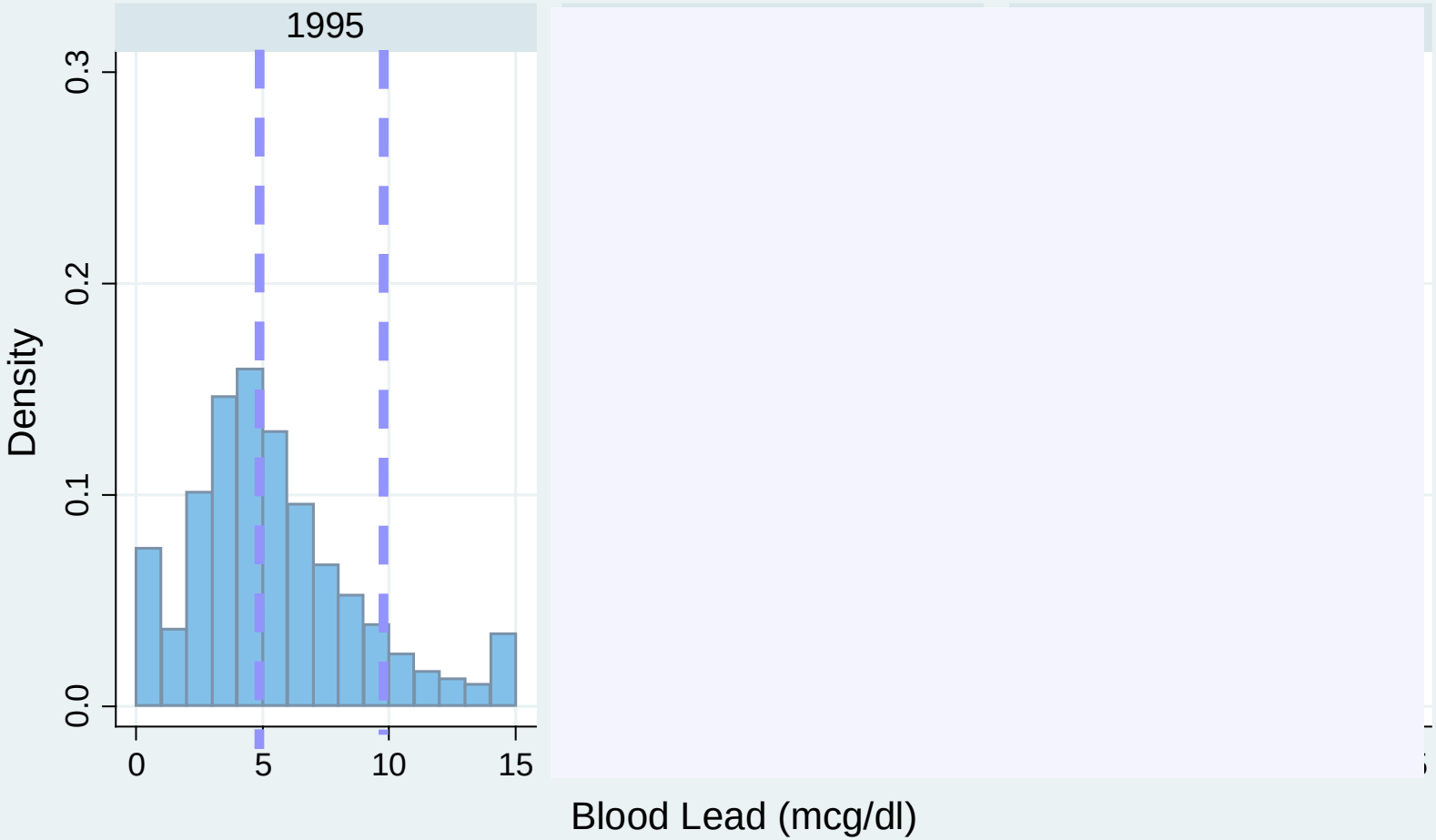


Source: Dr. Rob Fischer, co-director, Center on Urban Poverty and Community Development, Case Western Reserve University; data from the Ohio Department of Health

Reproduced from: Lisa Nelson, 2016. "Lead Poisoning and the Children of Cuyahoga County," Community Development Brief, Federal Reserve Bank of Cleveland, August 2016

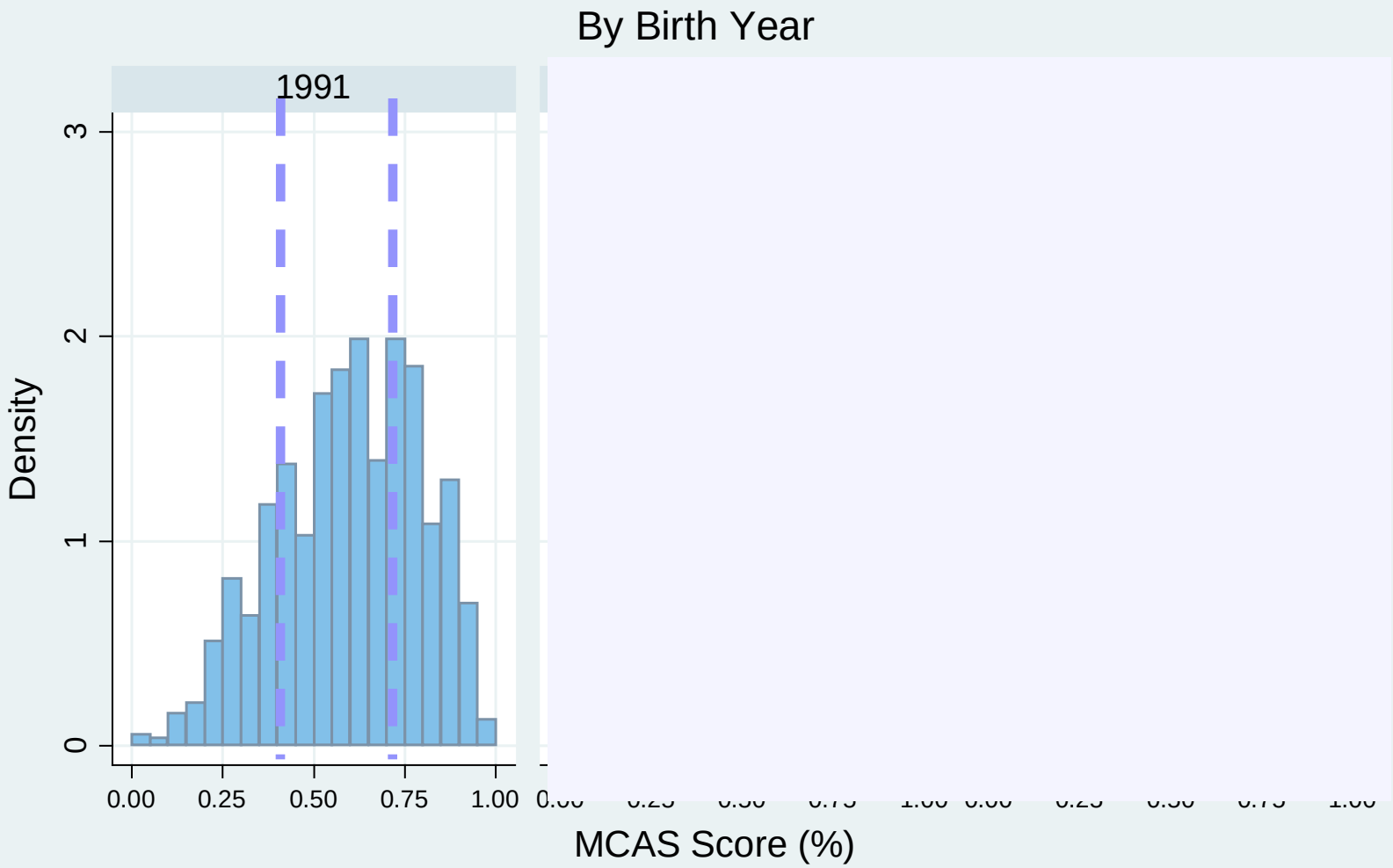
Massachusetts Childhood Blood Lead Distributions

By Birth Year

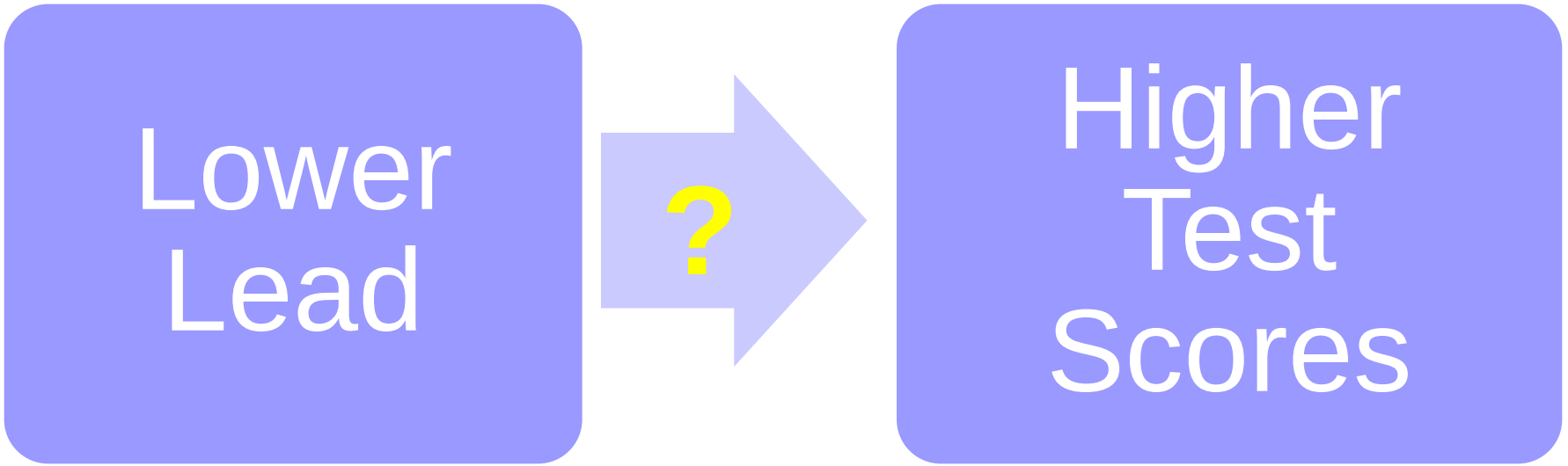


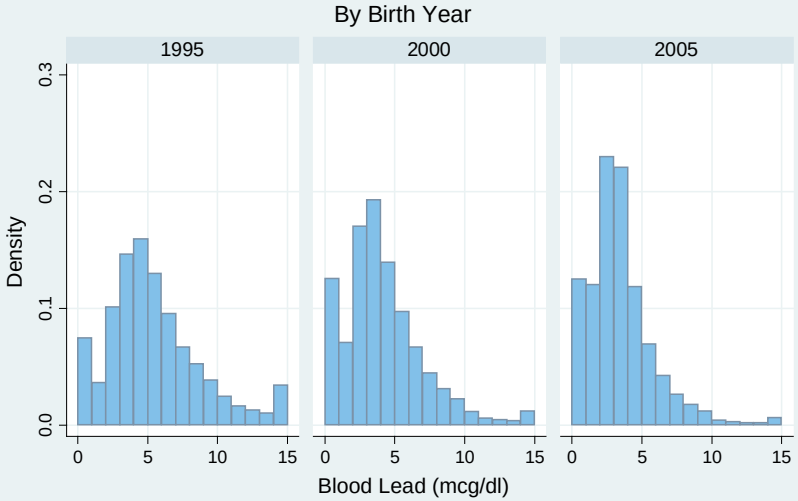
Notes: Author's calculations on individual MA CLPPP data, screened children.

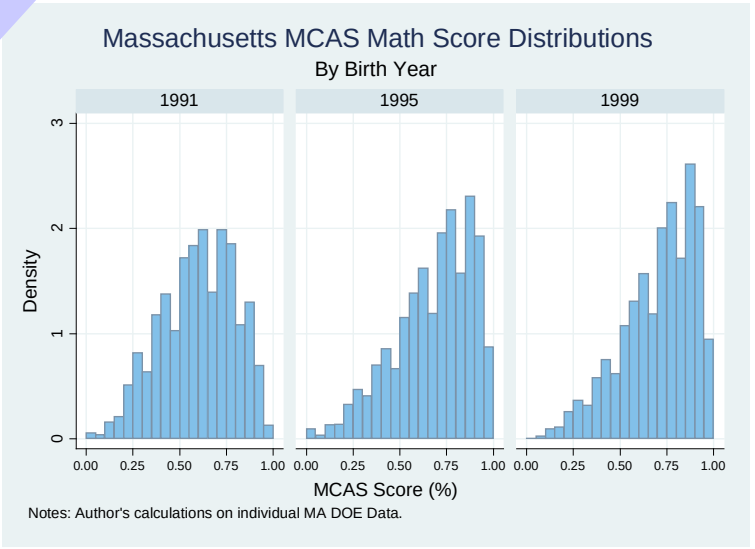
Massachusetts MCAS Math Score Distributions



Notes: Author's calculations on individual MA DOE Data.

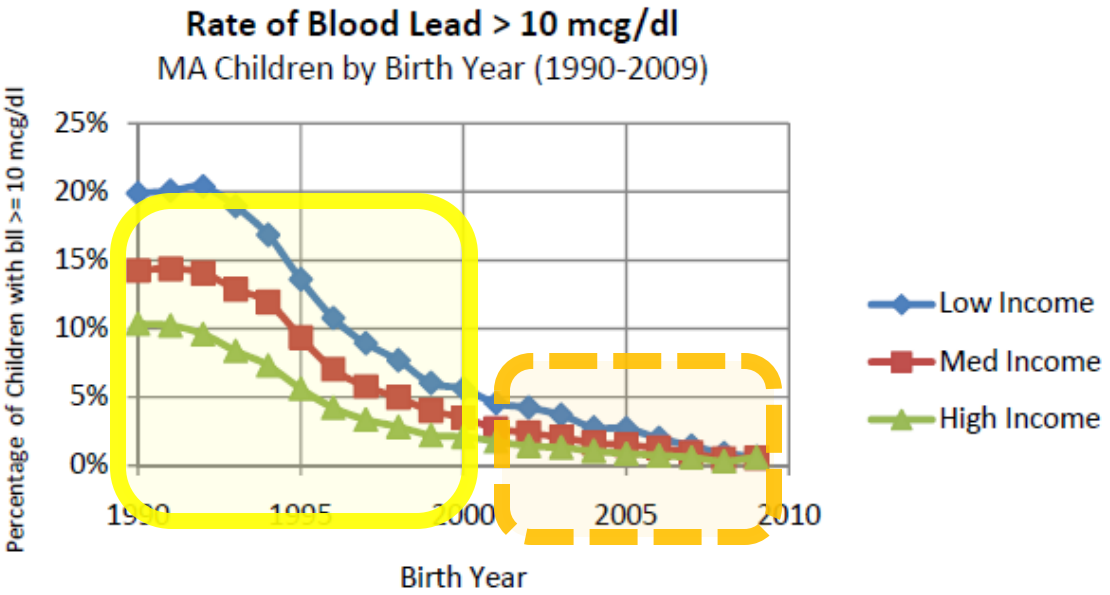

Lower Lead
?
Higher Test Scores


Massachusetts Childhood Blood Lead Distributions
By Birth Year
1995
2000
2005
Density
0.0
0.1
0.2
0.3
0
5
10
15
Blood Lead (mcg/dl)
Notes: Author's calculations on individual MA CLPPP data, screened children.


Massachusetts MCAS Math Score Distributions
By Birth Year
1991
1995
1999
Density
0
1
2
3
0.00
0.25
0.50
0.75
1.00
MCAS Score (%)
Notes: Author's calculations on individual MA DOE Data.

Cohorts for Analysis

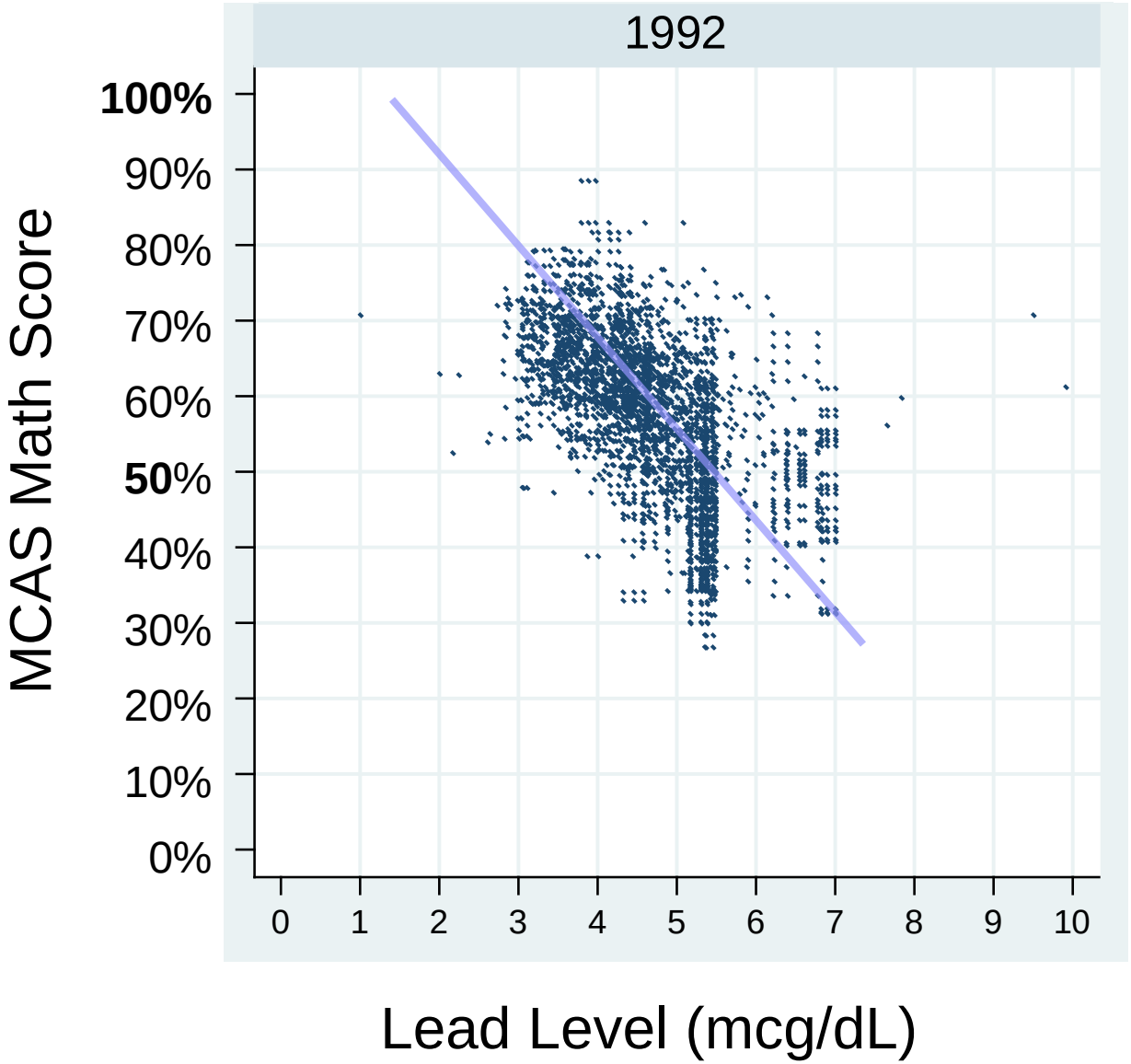
Data to use:
- Cohorts born between 1991 and 2000
- Lead measured in first 5 years of life
- MCAS Test scores from 3rd, 4th, 6th, and 7th grades
- MCAS Tests taken in years 2001 to 2009



Birth Year	Cohort Size		
	Lead	MCAS	% L/M
1991	77,456	79,362	98%
1992	75,991	77,870	98%
1993	73,341	75,996	97%
1994	67,347	74,122	91%
1995	66,519	73,381	91%
1996	67,126	71,620	94%
1997	66,780	71,023	94%
1998	64,675	71,754	90%
1999	63,258	70,942	89%
2000	63,148	71,109	89%

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

Cross-Section: MCAS vs. Lead



Another approach: Differences in differences

- Divide towns into those that had big declines in lead and those that had small declines in lead.
- Compare the test score changes in those two groups of towns.
- Do we see bigger test score improvements in the towns that experienced bigger declines in lead?

Where lead goes down, …. test scores go up

Outcome Measure	*DD2* [a,c]	
Mean score on MCAS		
3rd grade English	0.029 **	(0.010)
4th grade English	0.010	(0.009)
4th grade Math	0.045 **	(0.124)

Towns with larger *decreases* in **lead** in the 1990s showed larger *improvements* in MCAS **scores** in the 2000s.

Where lead goes down, …. failure rates go down

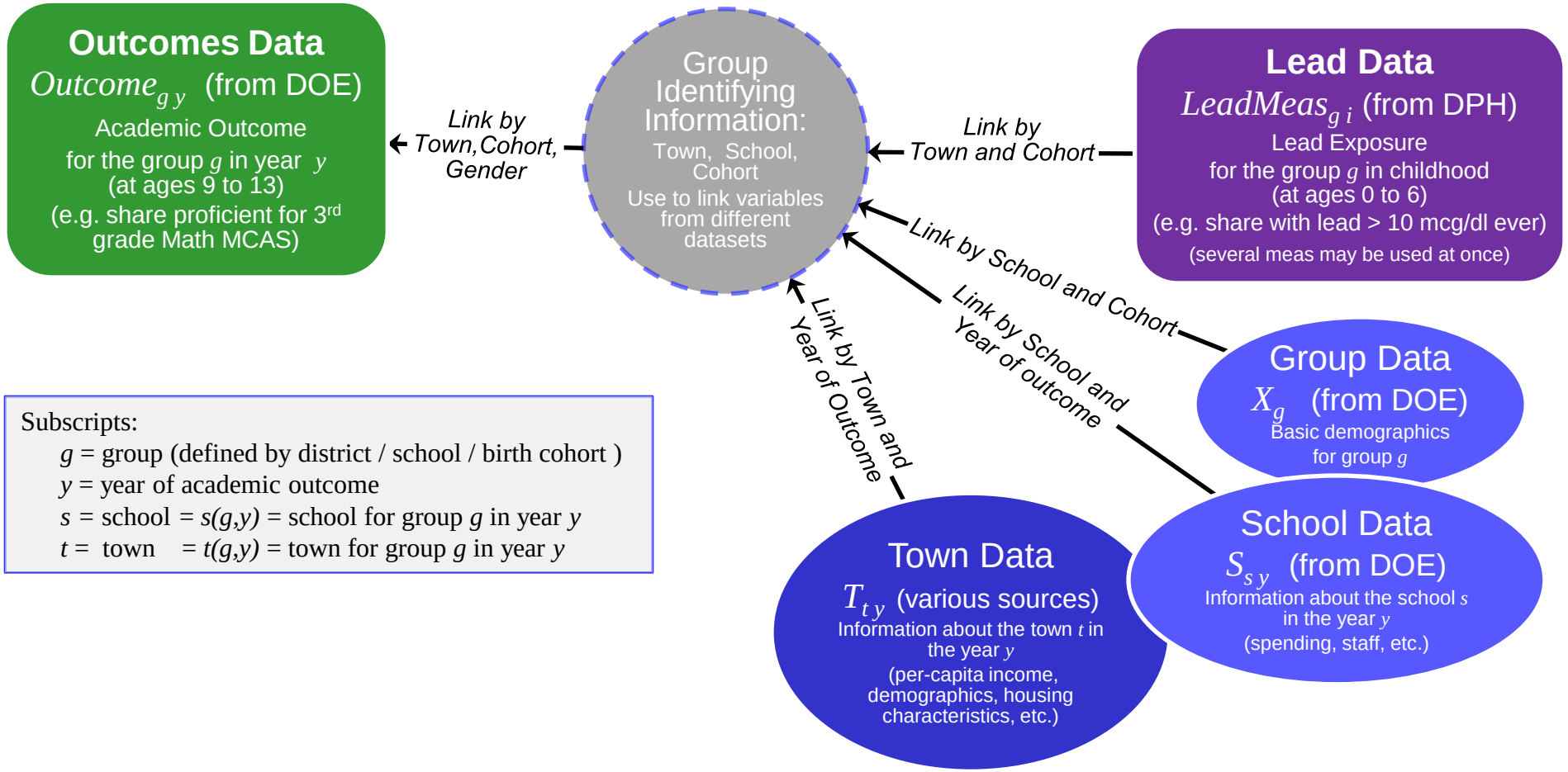
Outcome Measure	*DD2* [a,c]	
Share Unsatisfactory on MCAS		
3rd grade English	-0.052 **	(0.022)
4th grade English	-0.038	(0.027)
4th grade Math	-0.065 **	(0.027)

Towns with larger *decreases* in **lead** in the 1990s showed larger *decreases* in MCAS **failure** rates in the 2000s.

Analysis Plan

$$Outcome_{g\,y} = \beta_0 + \sum_i \alpha_i LeadMeas_{g\,i} + \underbrace{X_g \beta_1}_{\text{Group Data}} + \underbrace{S_{s\,y} \beta_2}_{\text{School Data}} + \underbrace{T_{t\,y} \beta_3}_{\text{Town Data}} + \gamma_y + \varepsilon_{g\,y}$$

Fixed Effects



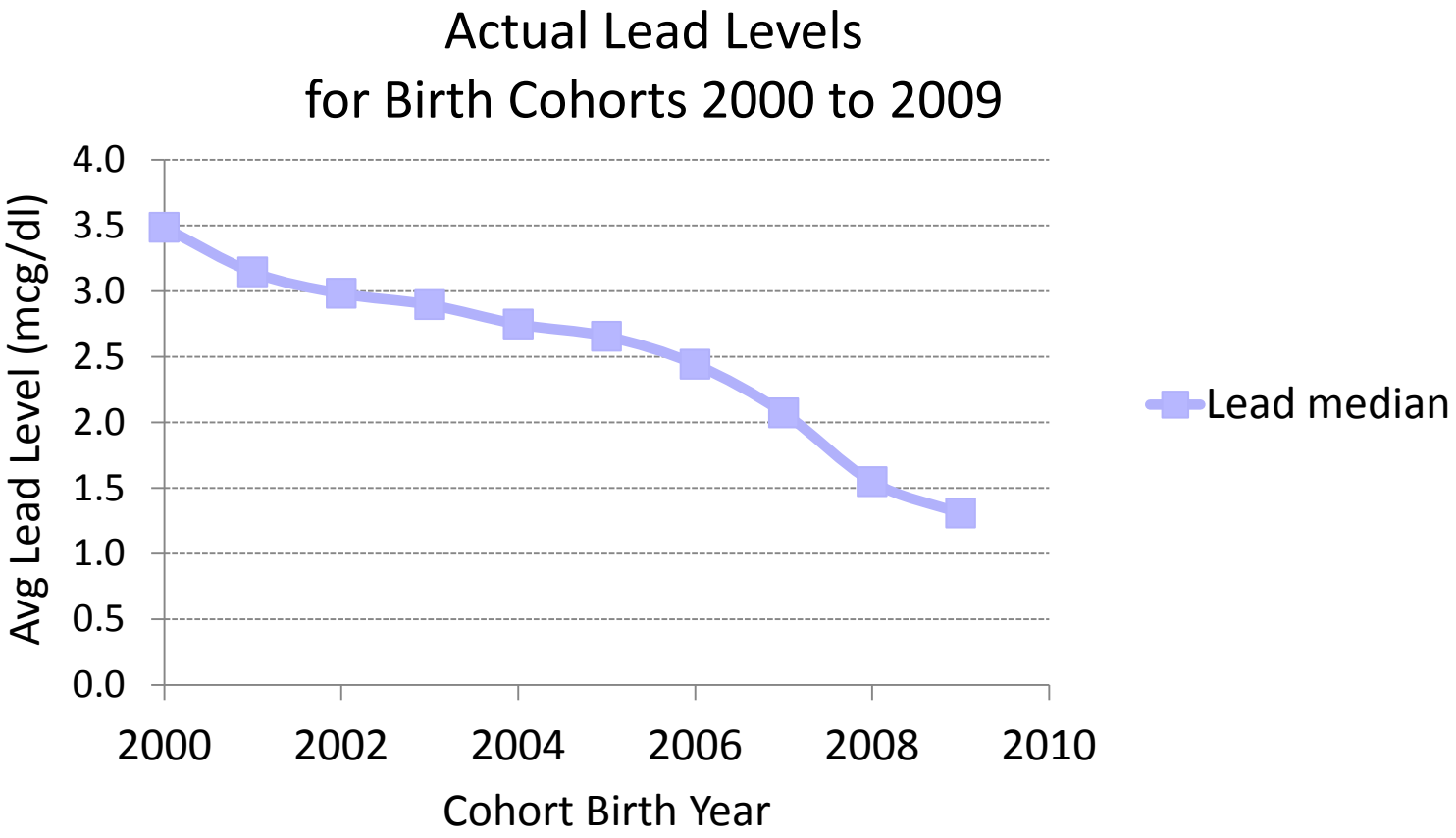
Subscripts:

- g = group (defined by district / school / birth cohort)
- y = year of academic outcome
- s = school = $s(g,y)$ = school for group g in year y
- t = town = $t(g,y)$ = town for group g in year y

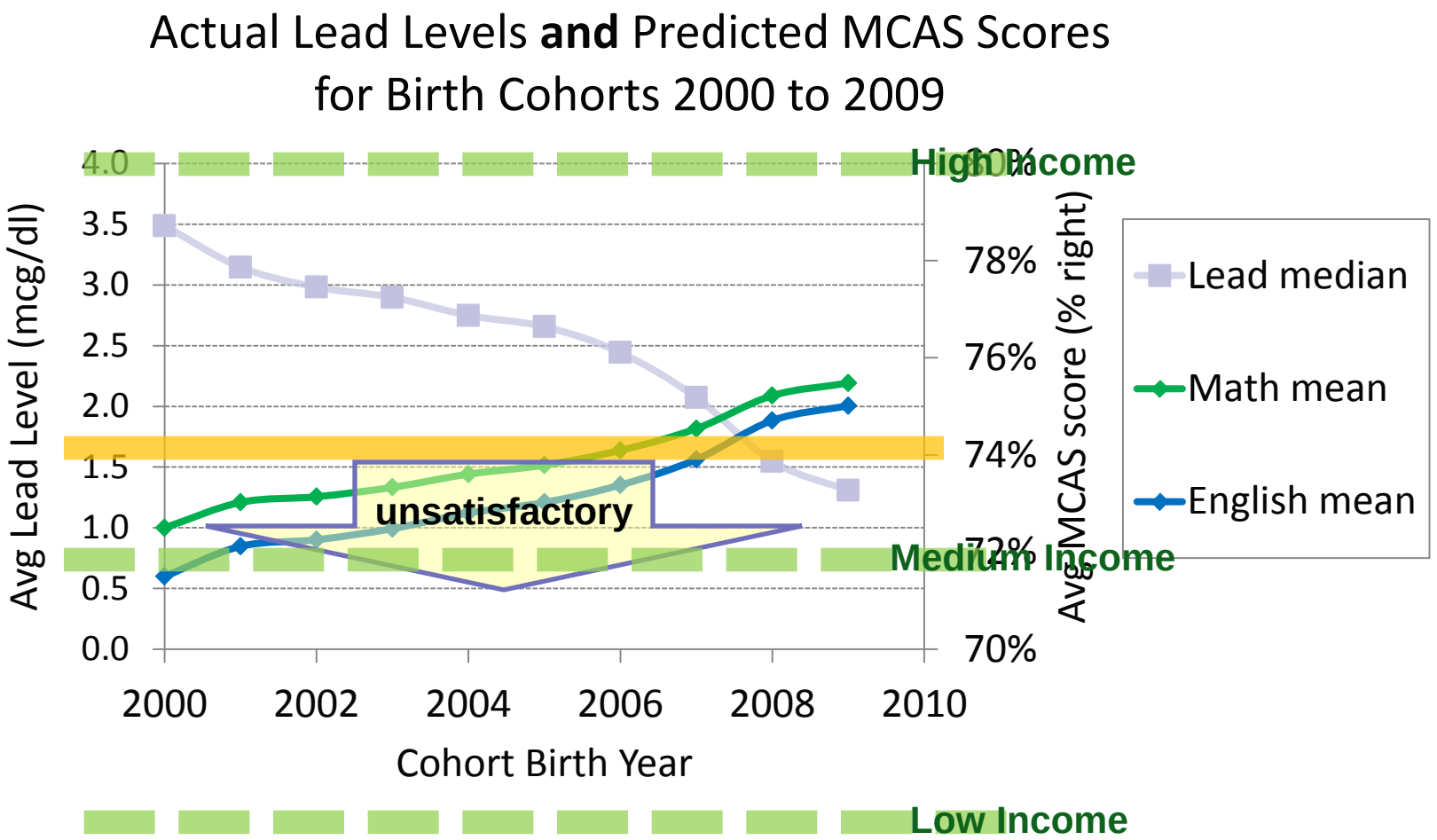
Table 5. Regression of Share Unsatisfactory MCAS on Share Lead in Certain Ranges.

Childhood Lead Measure(s)	*Subject*	(1) Base	(2) Weighted	(3) Include Year F.E.	(4) Include Town Chars	(5) Include School Chars	(6) Full
A. Share Lead > 10 mcg/dl	English	2.1739***	2.3454***	3.5361***	0.7881***	0.4134***	0.2096***
		(0.0873)	(0.0846)	(0.1320)	(0.0964)	(0.0781)	(0.0774)
Share Lead > 10 mcg/dl	Math	2.8899***	3.0666***	3.3172***	0.7732***	0.4407***	0.2030**
		(0.0973)	(0.0923)	(0.1316)	(0.1082)	(0.0958)	(0.0918)
B. Share Lead > 20 mcg/dl	English	10.5694***	15.3695***	13.5419***	3.6188***	1.7003***	1.0240***
		(1.3285)	(0.8760)	(1.8469)	(0.4128)	(0.3433)	(0.3006)
Share Lead > 20 mcg/dl	Math	12.9402***	18.6820***	12.1698***	3.3826***	1.6157***	0.9464**
		(1.6098)	(0.9750)	(1.7209)	(0.4795)	(0.4412)	(0.3907)
C. Share Lead 10-20 mcg/dl	English	2.2066***	2.2373***	3.7646***	0.7337***	0.4287***	0.1979**
		(0.1116)	(0.1077)	(0.1563)	(0.1173)	(0.0938)	(0.0940)
Share Lead > 20 mcg/dl	English	3.0101***	4.7464***	4.0348***	2.0627***	0.7815**	0.6445**
		(0.7210)	(0.6448)	(0.8826)	(0.3652)	(0.3200)	(0.2973)
Share Lead 10-20 mcg/dl	Math	3.0483***	3.1156***	3.5532***	0.7324***	0.4781***	0.1927*
		(0.1253)	(0.1177)	(0.1602)	(0.1258)	(0.1105)	(0.1066)
Share Lead > 20 mcg/dl	Math	3.1230***	4.5214***	3.4972***	1.7531***	0.5607	0.5581
		(0.7345)	(0.5887)	(0.8106)	(0.3993)	(0.3948)	(0.3600)

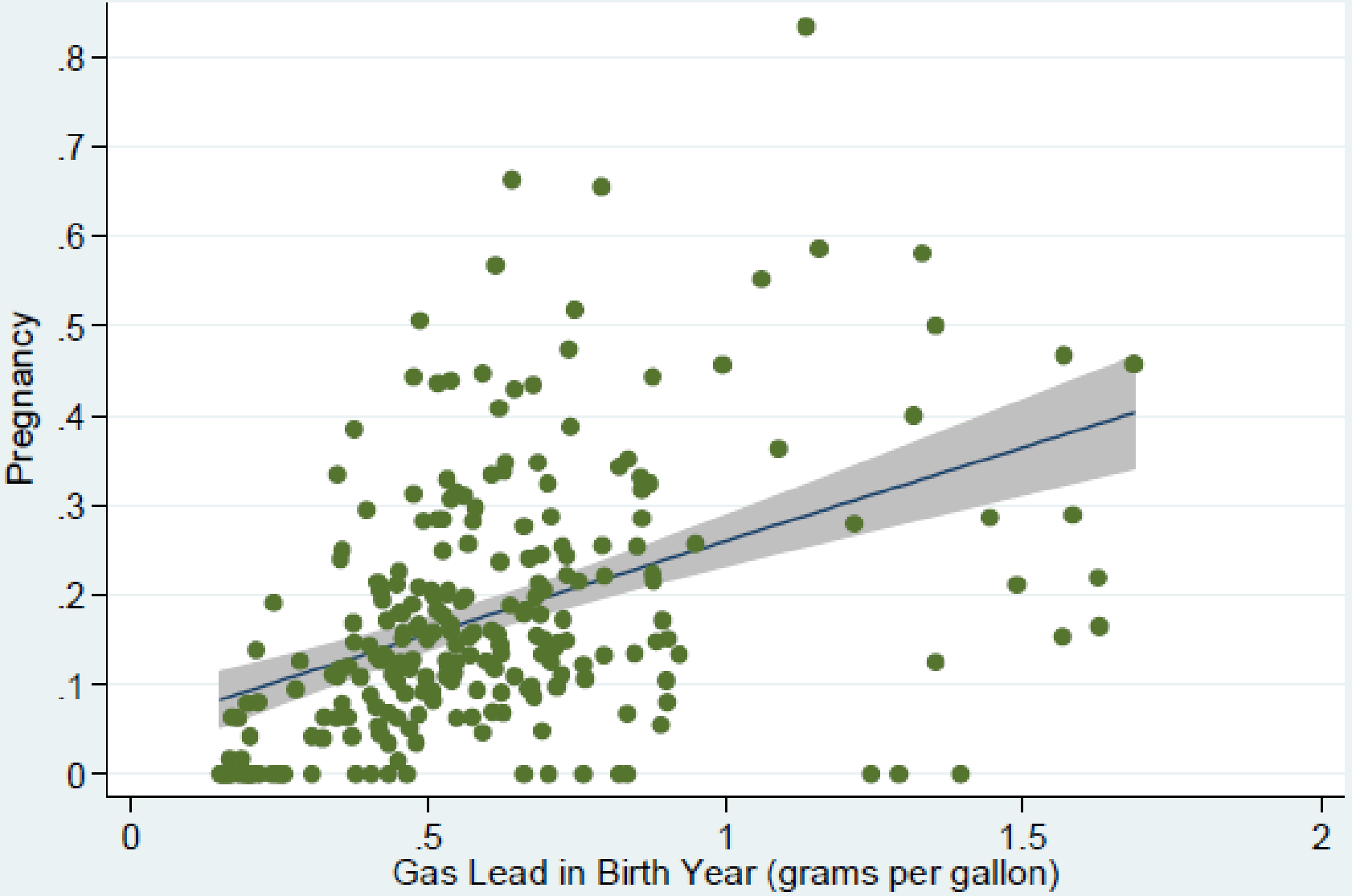
Lead levels declined further in the 2000s…



…so test scores should rise in the future



Teen Pregnancy vs. Gasoline Lead



Source: Jessica W. Reyes. "Lead Exposure and Behavior: Effects on Aggression and Risky Behavior among Children and Adolescents," *Economic Inquiry*, 53:3, July 2015.

Lifetime Costs per Child of 1 mcg/dl

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.