Childhood Lead Exposure in Illinois and Leeds

Frank DiTraglia

Department of Economics, University of Oxford

About Me

Econometrics

Causal Inference, Spillovers, Measurement Error, Model Selection, Bayesian Inference

Applied Work

Childhood Lead Exposure, Pawn Lending in Mexico City, Colombian Civil conflict

Background on Childhood Lead Exposure

Lead is a potent neurotoxin

- Toxic whether inhaled or ingested
- Most harmful to young children
- Harm from even low levels of exposure

Didn't we get rid of the lead?

- Lead paint and pipes in older homes
- Soil near major roads still contaminated
- Industrial pollution, traditional products

US Policy Landscape

- EPA regulations for renovation (lead paint)
- Mandated screening of children on Medicaid
- Screening for representative sample: NHANES

Some Econ Papers on Lead Exposure

Aizer & Currie (2018; AEJ Applied)

Lower BLLs explain 75% of decline in school suspensions from 1994-2015 in RI

Aizer, Currie, Simon & Vivier (2019; ReStat)

Low levels of lead (BLL ≤ 5) have a discernible negative affect on test scores.

Groenqvist, Nilsson & Robling (2020; JPE)

Long-term effects on human capital and crime from low doses of lead

Billings & Schnepel (2018; AEJ Applied)

Early interventions largely reverse negative effects for lead-exposed children.

Abbasi, DiTraglia, Gazze & Pals (2023; J. Health Econ.)

Estimate geographic distribution of undetected lead poisoning in Illinois; evaluate alternative screening policies.

Why did I start thinking about this?

Sign in
Subscribe
The Guardian
News website of the year
News Opinion Sport Culture Lifestyle
World ▸ Europe US Americas Asia Australia Middle East Africa Inequality

US news

This article is more than **1 month old**

Half of US adults were exposed to harmful lead levels as kids, study finds

Researcher calls findings 'infuriating' as team finds significant impact on cognitive development

Associated Press

Tue 8 Mar 2022 00.20 GMT

Over 170 million Americans who were adults in 2015 were exposed to harmful levels of lead as children, a new study estimates.

Researchers used blood-lead level, census and leaded gasoline consumption data to examine how widespread early childhood lead exposure was in the country between 1940 and 2015.

Sign in
Subscribe
The Guardian
News website of the year
News Opinion Sport Culture Lifestyle
World ▸ Europe US Americas Asia Australia Middle East Africa Inequality

America's dirty divide

'We're losing IQ points': the lead poisoning crisis unfolding among US children

The US banned lead 30 years ago. So why are thousands of kids being poisoned every year?

Supported by

OPEN SOCIETY FOUNDATIONS

About this content

Erin McCormick *in Rhode Island and* **Eric Lutz**

Wed 8 Dec 2021 10.00 GMT

Nine-year-old Turokk Dow loves spelling, airplanes and basketball. He is learning to read and write in his third grade classroom.

Sign in
Subscribe
The Guardian
News website of the year
News Opinion Sport Culture Lifestyle
Environment ▸ Climate crisis Wildlife Energy Pollution

Our unequal earth

This article is more than **2 years old**

'It was everywhere': how lead is poisoning America's poorest children

The toxin has endangered hundreds of thousands of kids. But parents in the hardest-hit neighborhoods may never be warned of the threat

Supported by

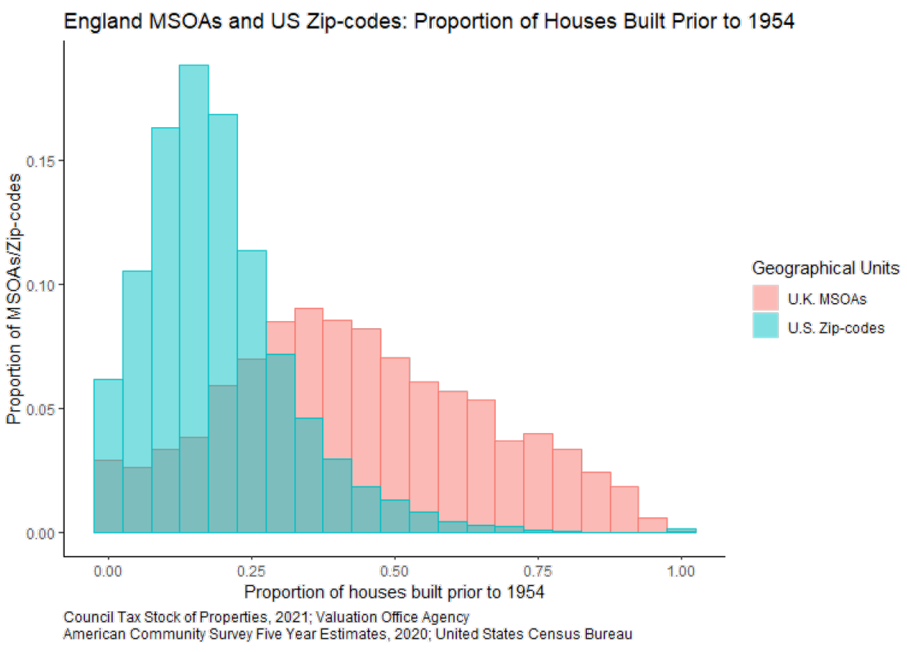
11th Hour Project

About this content

Nina Lakhani *in Philadelphia*

Wed 26 Feb 2020 09.00 GMT

Shanava Ball did everything right during her pregnancy: she https://www.theguardian.com/...


England MSOAs and US Zip-codes: Proportion of Houses Built Prior to 1954
Proportion of MSOAs/Zip-codes
0.15
0.10
0.05
0.00
0.00
0.25
0.50
0.75
1.00
Proportion of houses built prior to 1954
Geographical Units
U.K. MSOAs
U.S. Zip-codes
Council Tax Stock of Properties, 2021; Valuation Office Agency
American Community Survey Five Year Estimates, 2020; United States Census Bureau

There is no lead screening in the UK whatsoever.

2018 National Screening Committee Report

The volume, quality, and direction of evidence published since 2012 does not indicate that screening for elevated BLLs should be recommended in the UK. Several uncertainties remain across key criteria including: lack of evidence that elevated BLLs in children is an important health problem in terms of UK prevalence.

2019 Lead Exposure in Children Surveillance System Report

There are no recent comprehensive survey data estimating how many children in England are exposed to lead.

2021 Public Health England (now HSA)

Public health intervention level for lead halved from 10 to 5μg/dl.

ECLIPS – Pilot a Childhood Lead Screening Program

Elevated Childhood Lead Interagency Prevalence Study

- Jane Entwistle, Lindsay Bramwell, *Northumbria*
- Frank DiTraglia, *Oxford*
- Ludovica Gazze, *Warwick*
- Carys Lippiatt, *Leeds Teaching Hospitals*
- Priya Mondal, Ovnair Sepai, *UKHSA*
- Jackie Morton, *Health & Safety Executive*
- Caroline Taylor, *Bristol*

UKRI Cross Research Countil Responsive Mode Scheme

- Funded from Jan 2025 – Dec 2027
- Pilot a home test for childhood lead exposure in Leeds
- Finger-prick test using Capitainer (at right)

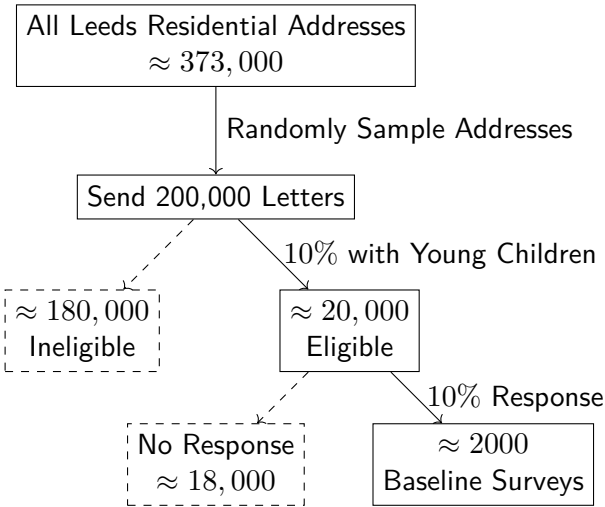
Learning as much as we can even if fail to get usable samples

- What fraction of families are willing to participate in home screening?
- Which families are willing to participate? (Selection into testing)
  - Dutz et al (2023) "What Drives (Gaps In) Scientific Study Participation?"
  - 6% un-incentivized response rate: 10% for low poverty, 2% for high
  - 17% with $100 incentive: 24% for low poverty, 8% for high
- Estimates of exposure risk (housing age etc) correlate negatively with income
- Which families are more likely to return a valid sample?
- What motivates participation? Info about child's health? Altruism?

Testing Details

- Device requires one good-sized drop of blood (≈ 17 microliters)
- Extracting it, requires parents to apply a lancet to child's finger (1-2 mm depth)
- Planned for kids 6 months to 6 years, but 6 months seems less likely now
- Anecdote from our colleague Joe: hard to get your kid to cooperate!

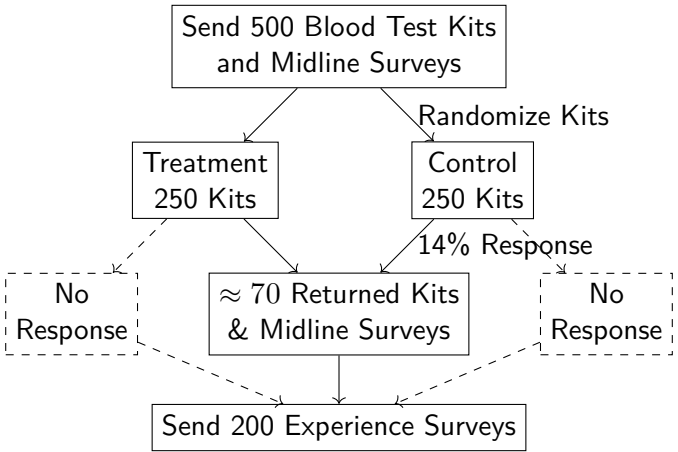
Overview of Phase I – From Our Proposal



5 GBP gift card for sign-up and baseline survey completion

Overview of Phase II – From Our Proposal

Baseline survey & census: choose probs of sending each household a kit (2000 to 500)



35 GBP for returned sample / midline survey; 10 GBP for experience survey

What we'd like feedback on today

Randomized Outreach Messages

Test effect of different outreach messages on participation; what's interesting here?

Sampling Plan

Two-stage, adaptive, stratified sampling plan. Comments / concerns?

Randomized Test Kits

If we have time: what might be interesting to randomize here?

Randomized Messaging: Overview

What to put in our recruiting letter?

Many possibilities: why not randomize something to see what improves take-up?

Possible Comparisons

- Personalized Risk Information
- Blood Testing Language
- Risk Communication Level
- Lead Exposure Sources
- Framing Benefits from Participation

Questions for our Expert Audience

1. Which comparisons are most interesting from a research perspective?
2. What to pick as a baseline / control from among the less interesting questions?

Recruitment Messaging: Details

Personalized Risk Information

- Merged EPC certificates for Leeds with residential addresses
- Gives us age of 250k properties (out of $\approx$ 373k)
- "Our records indicate that your home was built before XXXX so it might have lead paint or pipes. Taking part can help you learn if these may affect your child's health."

Lead Exposure Sources

- "Lead can be found in various products including XXXX. Taking part can help you learn if any of these affect your child."
- Does it matter which sources we list? How many? Child-relevant only?

Recruitment Messaging: Details

Blood Testing Language

- Consent forms and participation leaflet will explain about the blood test. - Should we mention blood in the recruitment letter itself?
- Con: people may not read further. Pro: only committed participants proceed.

Framing Benefits from Participation

- Private benefits “learn information about your child’s health”
- Altruism / Public Health: “help us learn how to improve the health of UK children”

Stratified Sampling

Budget

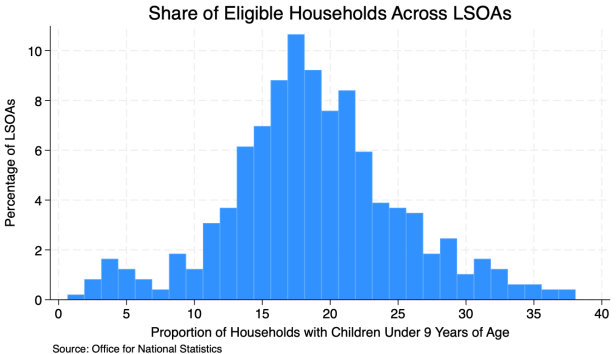
Send outreach letters to $\approx 40\%$ of residential addresses in Leeds.

Simple Random Sample

Choose 40% of addresses at random, without replacement.

Stratified Random Sample

More letters to LSOAs where more households have kids (census)



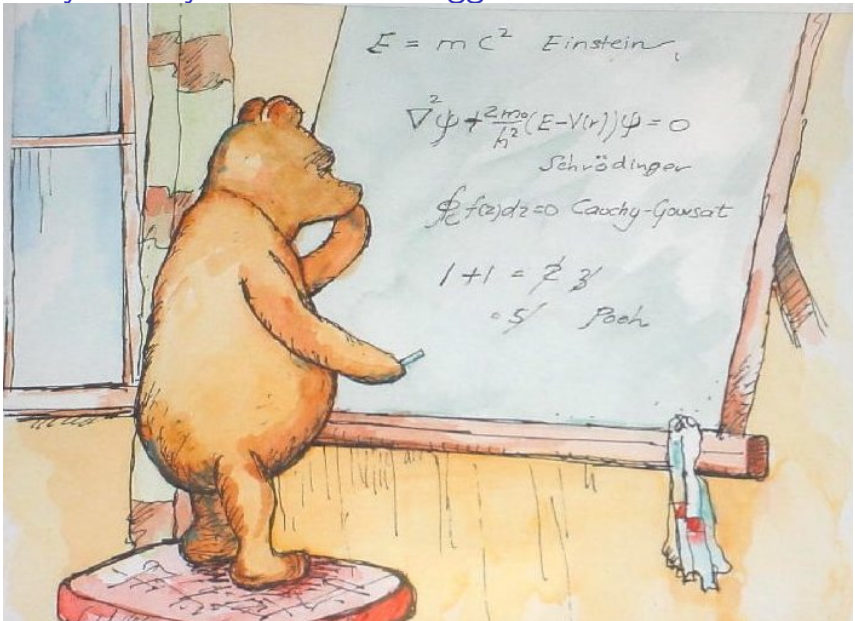
Adaptive Sampling?

Considering sending 20% of letters initially, modeling the response rates based on LSOA & respondent characteristics and adjusting the sampling scheme for the remaining 80%

Randomized Test Kits

- We have the opportunity to randomize the test kits
- Considered a toy for kids, but hard to find something:
  - age-appropriate (6 months to 6 year!)
  - not choking hazard
  - fits in flat pack
- Considering stickers instead. Potentially randomize delayed reward / surprise?
  - Stickers in envelope to be opened afterwards?
- Other ideas?

Thank you for your time and suggestions!



People are talking about lead

- Prominent news stories, esp. Flint Michigan
- $15 billion for lead pipe remediation in 2021 US infrastructure bill
- Chicago Fed working on a project related to lead service line replacement
- People outside the Fed and White House are involved too...

How I got interested in this topic.

Sign in
Subscribe
The Guardian
News website of the year
News Opinion Sport Culture Lifestyle
World ▸ Europe US Americas Asia Australia Middle East Africa Inequality

US news

This article is more than **1 month old**

Half of US adults were exposed to harmful lead levels as kids, study finds

Researcher calls findings 'infuriating' as team finds significant impact on cognitive development

Associated Press

Tue 8 Mar 2022 00.20 GMT

Over 170 million Americans who were adults in 2015 were exposed to harmful levels of lead as children, a new study estimates.

Researchers used blood-lead level, census and leaded gasoline consumption data to examine how widespread early childhood lead exposure was in the country between 1940 and 2015.

Sign in
Subscribe
The Guardian
News website of the year
News Opinion Sport Culture Lifestyle
World ▸ Europe US Americas Asia Australia Middle East Africa Inequality

America's dirty divide

'We're losing IQ points': the lead poisoning crisis unfolding among US children

The US banned lead 30 years ago. So why are thousands of kids being poisoned every year?

Supported by

OPEN SOCIETY FOUNDATIONS

About this content

Erin McCormick *in Rhode Island and* **Eric Lutz**

Wed 8 Dec 2021 10.00 GMT

Nine-year-old Turokk Dow loves spelling, airplanes and basketball. He is learning to read and write in his third grade classroom.

Sign in
Subscribe
The Guardian
News website of the year
News Opinion Sport Culture Lifestyle
Environment ▸ Climate crisis Wildlife Energy Pollution

Our unequal earth

This article is more than **2 years old**

'It was everywhere': how lead is poisoning America's poorest children

The toxin has endangered hundreds of thousands of kids. But parents in the hardest-hit neighborhoods may never be warned of the threat

Supported by

11th Hour Project

About this content

Nina Lakhani *in Philadelphia*

Wed 26 Feb 2020 09.00 GMT

Shanava Ball did everything right during her pregnancy: she https://www.theguardian.com/...

Background

Some questions you may be asking yourself

1. Is lead really a big deal?
2. Didn't we get rid of all the lead?
3. What should we do about it?
4. Why should economists study this?

What's so bad about lead?

Lead is a potent neurotoxin

- Toxic whether inhaled or ingested: "mimics" calcium, disrupting all biological processes that depend on it.
- Harms reproductive, hematopoietic, endocrine, renal systems.
- Particularly harmful to **central nervous system**: calcium crucial for neurotransmission $\implies$ damage to prefrontal cortex, hippocampus, cerebellum

Lead is most harmful at younger ages

- Permanent damage to developing nervous systems.
- Blood-brain barrier more permeable in young children.
- Digestive systems of children more likely to absorb ingested lead.
- Lead accumulates in bone and *stays there* even after leaving the blood.
- Young children put things in their mouths (paint chips, soil); lead **tastes sweet**.
- E.g. Roman sweetener/preservative *sapa* aka *defrutum*: concentrated grape juice boiled in lead vessels

Didn't we get rid of all the lead?

We largely stopped *adding* lead, but much remains in place.

Leaded gasoline

- Responsible for the overwhelming majority of lead exposure during 20th century
- Phased out for cars between 1973 and 1995 in US; still used for small planes
- Soil near major roads remains contaminated.

Lead paint

- Ubiquitous in first half of 20th century; US ban for residential use in 1978
- Likely the main exposure source today, after phaseout of leaded gasoline
- HUD estimate: 20% of US homes with small children still have lead paint
- Ingested, or inhaled in form of dust (EPA requirements for renovations)

Lead pipes

- It's complicated...

Lead pipes: it's complicated

Past, Present & Future of Lead Service Lines

- US banned lead service lines in 1986; EPA estimates 6 million remain today.
- Locations of lead service lines often unknown: statistical modeling.
- Chicago: greatest number of lead service lines of any city in the US (400,000 est.)
- Illinois: plans to replace remaining lead service lines over 50 years.

It depends on the water

- **Scale**: plaque on inside of pipes that prevents lead from leaching into water.
- Water hardness (mineral content) tends to increase development of scale.
- Phosphates can be added to artificially create scale: compounds bind to lead.
- U-shaped relationship: water pH and lead solubility
- (pH $6 \uparrow 7$) $\implies$ (water-lead $\downarrow$) 50 to 90%, depending on above.

DC 2002; Flint Michigan 2014

- Changes in water sources/treatment $\implies$ sudden corrosion of protective plaque.
- High levels of lead flush into the water supply (need to test at the tap)

Measuring Lead Exposure in the US

Blood Lead Levels (BLLs)

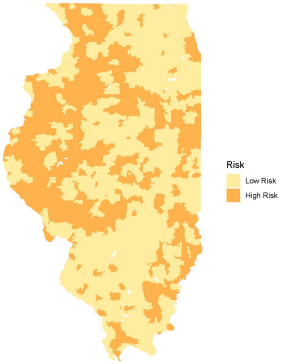
- BLLs, either venous or capillary (finger prick), proxy for lead exposure.
- Measured in micrograms per decliter (μg/dl)
- Best we can do, but not ideal:
  - Half life of lead in blood ≈ 36 days: "instantaneous" versus cumulative exposure
  - Venous tests are more accurate, but still noisy: measurement error

Screening

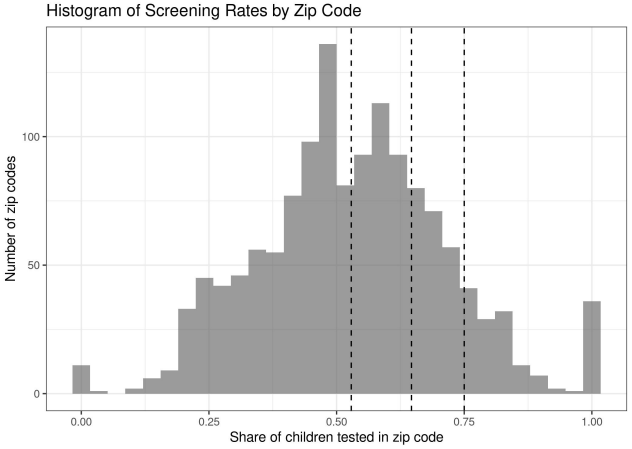
- National Health and Nutrition Evaluation Survey (NHANES): venous BLLs, representative cross-section
- Various screening programs run by the states
- Federal guidelines mandate screening of all children on Medicaid at ages 1 and 2.
- Some states have *de jure* universal screening; others have targeted screening
  - IL Dept. of Public Health designates zip codes as "high risk" based on housing age and % of children below 200% of poverty line.

Targeted Screening in Illinois: 2010-2014 Birth Cohorts

High and low-risk zips



Screening compliance in high-risk zips



Blood Lead Levels (BLLs): how high is too high?

- 1991-2012 CDC considered BLL ≥ 10 *elevated*; since 2012 BLL ≥ 5
- Essentially arbitrary: 97.5%-tile, most children no longer exposed to lead
- "No safe level of lead" but "the dose makes the poison" and BLLs have declined
- Clear **symptoms** of lead poisoning (anemia) and acute harm: BLL ≥ 40 μg/dl
- Permanent damage at levels too low to observe symptoms, e.g. lower IQ.

Policy Questions

1. Which children are still exposed to lead?
2. How harmful are **current exposure levels**?
3. Should we further reduce lead exposure?
4. Effective/cost-effective interventions?

Why should economists think about lead?

Methodology

- What are the causal effects of low levels of lead exposure?
- What are the causal effects of interventions to help lead-exposed children?
- Endogeneity and measurement error; these are in our wheelhouse as economists.

People make decisions

- Why do some families show up for screening while other don't?
- Can we improve screening take-up among high-risk children?

Cost/Benefit Analysis

- Public health researchers: "our policy goal should be zero lead."
- Economists: "keep doing something as long as the benefits exceed the costs"

What have economists contributed to the literature on lead?

Aizer & Currie (2018; AEJ Applied)

Lower BLLs explain 75% of decline in school suspensions from 1994-2015 in RI

- Individual-level BLLs linked to school disciplinary records in RI
- Sibing fixed effects and IV strategies
- Measurement error biases OLS but omitted variables appears less important

Aizer, Currie, Simon & Vivier (2019; ReStat)

Low levels of lead (BLL $\leq$ 5) have a discernible negative affect on test scores.

- Individual-level BLLs linked to 3rd-grade test scores for children from Rhode Island
- Census tract fixed effects; control for avg. test scores child's school & grade
- Two IV strategies; one exploiting multiple lead tests for majority of children.
- Measurement error attenuates the effect of lead.

What have economists contributed to the literature on lead?

Groenqvist, Nilsson & Robling (2020; JPE)

Long-term effects on human capital and crime from low doses of lead

- Sweden: leaded gasoline was *only* source of lead exposure; moss absorbs lead
- Difference-in-differences event study model: phaseout of leaded gas only affects neighborhoods with high pre-reform exposure (high traffic / closer to roads)
- Effects mainly operate through effects on non-cognitive skills

Billings & Schnepel (2018; AEJ Applied)

Early interventions largely reverse negative effects for lead-exposed children

- Two BLL measurements ≥ 10 trigger policy intervention in NC: nutritional, home inspection, lead remediation
- Measurement error creates something akin to an RD design: restrict attention to children whose first BLL measurement is ≥ 10
- Significant ITTs for antosocial behavior, primary & middle school performance

Hidden Hazards & Screening Policy: Predicting Undetected Lead Exposure in Illinois (with Abbasi, Pals and **Gazze**)

How should IL target lead screening?

Build novel dataset

- Link lead tests to geocoded birth records for IL children born from 2010 to 2014
- Merge with spatial characteristics that predict lead exposure: housing age, proximity to major roads, industrial lead emissions, etc.

Impute missing BLLs

- Rich set of individual and spatial controls, including all variables used to target.
- Selection observables (into testing) is plausible here
- Flexible machine learning models, tuned/evaluated with novel policy-relevant loss.

Policy Experiments

- How many children with elevated BLLs are missed by current screening?
- Can we reliably identify children who *shouldn't* be screened?
- Can we improve on the "high risk" zip code designations for IL?
- How best to target screening at the individual level?

If selection-on-observables is outlawed...

- Not completely airtight, but we go much further than existing work
- Policy discussions of targeted vs universal screening often assume BLLs *missing completely at random*, i.e. BLLs of tested and untested are equal on average.

Novel Policy-relevant Loss for Model Tuning/Evaluation

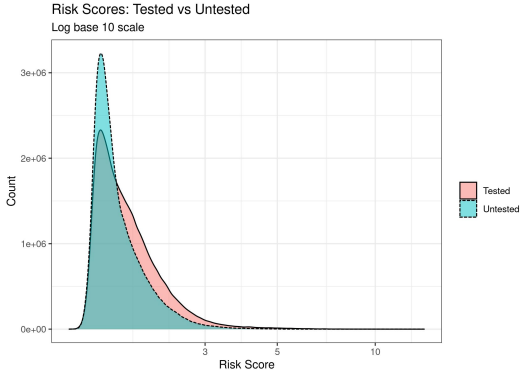
Naive Approach

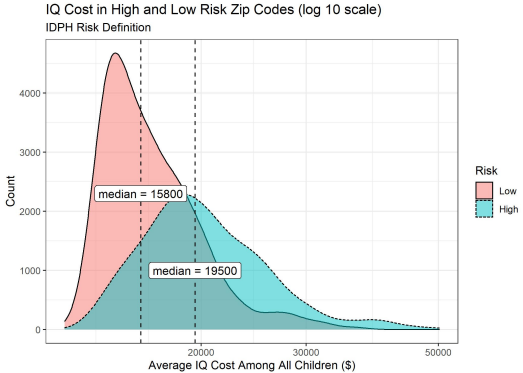
- Classification model to predict *elevated* BLLs: $1(\text{BLL} \geq 5)$ or 10.
- How to weigh false positive against false negatives?
- Is a BLL of 4.5 that you classify as "elevated" really a false positive?
- Much worse to classify a BLL of 20 as "not elevated" than a BLL of 5.5
- Cutoff of 5 or 10 is essentially arbitrary; why not 7?

Our Approach

- We prefer to identify children with higher BLL before those with lower BLLs.
- Score BLLs based on the *harms* they cause in dollars: *averted cost*
- Targeting function $r(X_i)$: ranks children based on observed covariates X_i.
- If you plan to screen n children, choose those with highest $r(X_i)$.
- Evaluate $r(\cdot)$ by comparing its *total* averted cost to infeasible optimum that perfectly ranks children from highest to lowest BLL.
- Develop cost-weighted targeting efficiency (CWTE) for tuning and evaluation.

Some Key Results



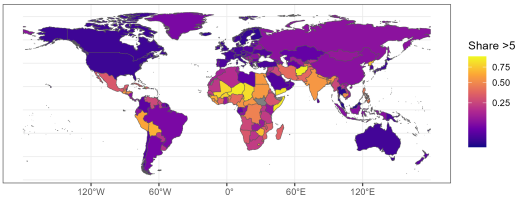


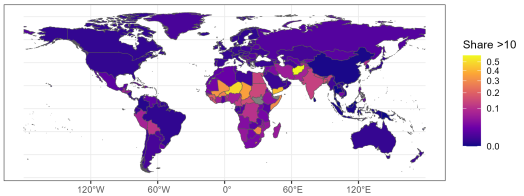
- The untested are, on average, higher risk than the tested: targeting works
- Estimate 6600 missed cases relative to 18,000 detected cases
- Over 80% of missed cases *should have been tested* under status quo: high risk
- Model-based targeted screening superior to status quo and "universal" screening

Ongoing and Future Work

Nature Review Article

- Retrospective: 20 years after leaded gasoline (with Ludovica Gazze et al.)
- Remaining global lead exposure; data gaps; back-of-the-envelope economic costs





What is the situation in the UK specifically?

2018 National Screening Committee Report

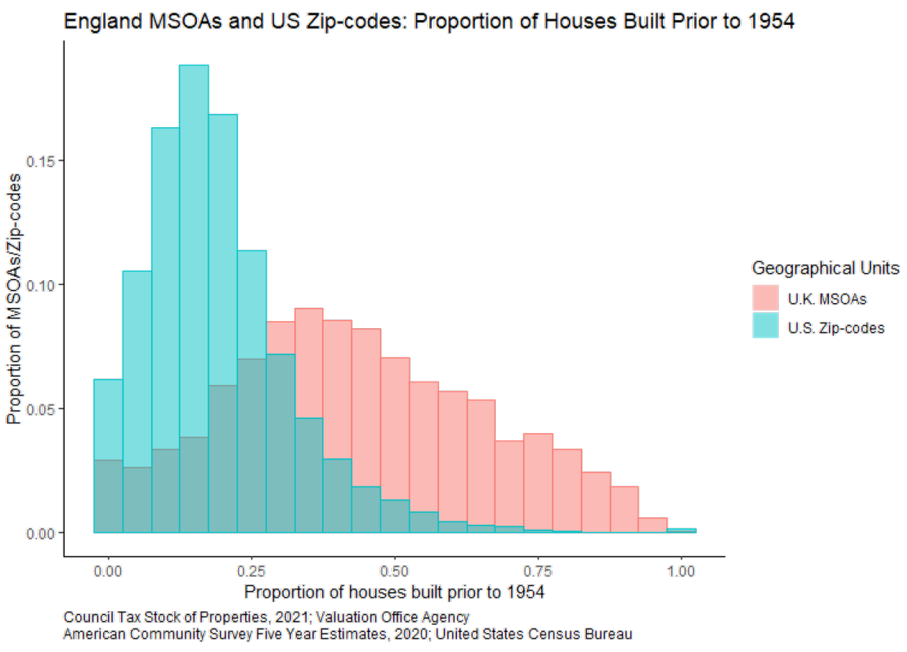
The volume, quality, and direction of evidence published since 2012 does not indicate that screening for elevated BLLs should be recommended in the UK. Several uncertainties remain across key criteria including: lack of evidence that elevated BLLs in children is an important health problem in terms of UK prevalence.

2019 Lead Exposure in Children Surveillance System Report

There are no recent comprehensive survey data estimating how many children in England are exposed to lead.

2021 Public Health England (now HSA)

Public health intervention level for lead halved from 10 to 5μg/dl.


England MSOAs and US Zip-codes: Proportion of Houses Built Prior to 1954
Proportion of MSOAs/Zip-codes
0.15
0.10
0.05
0.00
0.00
0.25
0.50
0.75
1.00
Proportion of houses built prior to 1954
Geographical Units
U.K. MSOAs
U.S. Zip-codes
Council Tax Stock of Properties, 2021; Valuation Office Agency
American Community Survey Five Year Estimates, 2020; United States Census Bureau

How serious is lead exposure in the UK?

ALSPAC Cohort Data

- High quality BLL data, but small samples and from the 1990s in Bristol only
- Just gained access; merged with housing age, distance to roads, pollution etc.

Lead Exposure in Children Surveillance Study

- Scanty, and heavily self-selected but only recent BLL data across the UK

State-Level US Data

- FOI: zip-level share tested & fraction elevated for 30 states over 10 years
- Merged with the usual predictors of exposure & demographics
- No individual data, so need a different solution to selection-into-testing (dist to provider? medicaid expansion?)

Combine/model these data sources to get a better approximation of BLLs;
Eventual goal: primary data collection on BLLs, exposure sources & outcomes