

The Hidden Costs of Recycling: Lead Exposure and Student Learning in Kenya

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Motivation: Recycling Benefits

Recycling is generally known in good light (US, EPA):

- Reduces the need for new landfills and methane emissions from landfills
- Prevents health risks and pollution resulting from virgin material production (extraction and processing of raw materials)
- Saves energy - extraction and processing of raw materials are very energy-intensive.
- Creates new jobs/employment and stimulates the development of greener technologies
- Reduces greenhouse gas emissions (from energy savings, incinerators, reduced methane emissions)
- Benefits are optimized when recycling is done safely. Rich economies tighten environmental regulations

Motivation: Lead Acid Battery Recycling

- Recycling benefits are universal across high-income countries (HICs) and Low- and middle-income countries (LMICs) and so are the risks
- Companies shift operations from regulated markets in HICs to unregulated markets in LMICs (Tanaka et al., 2022)
- In Sub-Saharan Africa (SSA), lead-acid battery recycling activities soared following tightening regulations in India (Gottesfeld et al., 2018; Will Fitzgibbon, 2023)
- SSA embraces firms setting up unregulated battery recycling plants to ease unemployment and blind to the externalities **COST?**
- What are the effects of battery recycling-driven lead exposure in these unregulated settings in SSA?
 - ▶ Particularly, what is the impact on human capital, an important economic outcome

Motivation: Student Learning

- The lack of learning in schools is a major concern in Sub-Saharan Africa (SSA) ([World Bank 2018](#))
- Is battery recycling-driven lead exposure an important contributor to the learning stagnation in SSA?
 - ▶ Many factors could contribute to limited learning, so the importance of lead is not obvious

- **Research Question:** How does random variation in the level of recycling-driven lead exposure impact student learning in Kenya
- **Context:** Leverages a sudden shift in the environmental quality following the opening of tens of battery recycling plants in Kenya in 2007
- **Data:** Uses student-level standardized test scores from a national secondary school qualifying exam to measure learning
- **Approach:** Uses matched event study and matched difference in differences approaches

Preview of Findings

- Recycling-driven lead exposure reduces student test scores by 0.05 standard deviations in Kenya
- The effect size comparable to gains from school-based programs that target learning improvement
- Bottom line: sizable effect size

Context: Lead-Acid Battery Recycling Plant

- Used Lead-Acid Battery Recycling Plant (ULABs) - Extract lead from used car batteries
- In 2007, tens of these plants were opened across the country
- 95,000 students attended schools within 4km radius of the plant at any given time between 2007 and 2010

Context: Lead Exposure

- Lead poisoning or exposure among children occurs via inhalation or ingestion. In this case from (ULABs) plant emissions
- Children more vulnerable:
 - ▶ their hand-to-mouth behavior and their natural inclination to explore their surroundings
 - ▶ their organ systems are not fully developed, and their mechanisms for metabolizing lead are relatively ineffective.
- Lead is then absorbed into the blood stream then gets deposited in the organs including the brain.
- This then impedes the development of the brain and disrupts neurological features, affecting cognition, attention, and short-term memory

Leverage variation in severity of schools exposure to lead emissions from the recycling plants, to run DiD regressions that

- compare children attending schools within 4km (6km, 8km, & 10km) of the battery recycling plant vs schools outside 10km but within 20km radius, and
- children who were exposed to lead pollution for more (younger) vs. fewer years (older) before taking a test

Specification

$$y_{ist} = \beta \cdot [\text{RecyclingPlant}_{ist} \text{XPotentialExposure}_i] + \gamma_s + \delta_t + \gamma_s \cdot t + \Gamma X'_{ist} + \varepsilon_{ist} \quad (1)$$

- y_{ist} is an outcome for student i in school s in exam year t . X'_{ist} are student level controls,
- $\text{RecyclingPlant}_{ist}$, an indicator that takes the value one if student i 's school s is within four (six, eight, or ten) km of a battery recycling plant
- $\text{PotentialExposure}_i$ is an indicator that takes the value one if student i belongs to the younger cohort at launch
- γ_s , and δ_t are school and exam year fixed effects respectively
- $\gamma_s \cdot \text{Trend}$ is an interaction of school fixed effects with a linear yearly time trend
- standard errors clustered at the school level (and repeated at plant level)

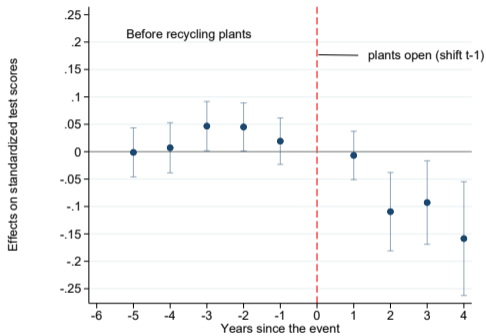
Event Study Design

$$y_{ist} = \sum_{\tau \neq 2006} \beta_{\tau} [\text{RecyclingPlant}_{ist} * \text{PotentialExposure}_i * 1[t = \tau]] + \gamma_s + \delta_t + \gamma_s \cdot t + \Gamma X'_{ist} + \varepsilon_{ist} \quad (2)$$

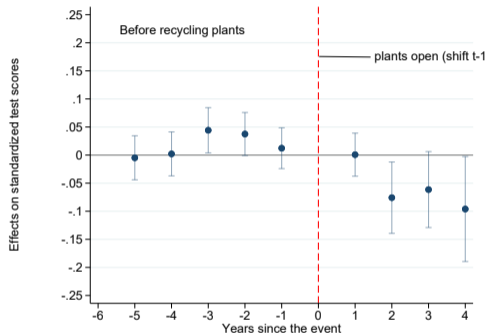
- reference category is the exam year just before battery recycling plants were opened ($\tau \neq 2006$)
- the rest of the controls remain as in equation (1)
- β_{τ} estimates the effect of belonging to the treatment group for each year from 2002 until 2010 (test score relative to the reference category)

- To measure learning, test score data is collected at individual level (end of primary school national exam test scores from 2002-2011)
 - ▶ **Source:** Kenya Certificate of Primary Education (KCPE)
- Student level covariates: student gender and year of birth
 - ▶ **Source:** Kenya Primary Schools Dataset (World Bank)
- School level covariates (for matching): num of classrooms | pupil-teacher ratio | student enrollment | num of teachers | type of sch | geo-location
 - ▶ **Source:** Census of pollution sites and plants (courtesy of TSIP by Pure Earth)
- Battery recycling plant data: geo-location, and soil lead levels collected at the plant level
 - ▶ **Source:** Census of pollution sites and plants (courtesy of TSIP by Pure Earth)

Impacts on Test Scores



(a) 4km Radius



(b) 6km Radius

Potential Mechanisms

- Health Channel:
 - ▶ Brain development impacted → child's cognitive ability impaired → diminishing comprehension in class and thus unable to keep up with the learning
 - ▶ Absenteeism: Medical complication keep students away from the classrooms for long periods of time → struggle to catch up
- Resource Reallocation:
 - ▶ Major medical complications → households reallocate resources away from child's education support to seeking healthcare for the child
 - ▶ Households reduce their labor supply to care for their sick children at home. This affects their income and thus resources available to the child

- Exposure to battery recycling-driven lead emissions reduces learning among students - a serious threat to future human capital
- These effects disappear for students attending schools beyond an 8 km radius of the recycling plant
- Policy implications: It is not about whether or not recycling plants should be opened, given the apparent benefits, but how they can open safely to eliminate or minimize the costs
- Further area of research: Improved monitoring → improved data → establish extent of exposure among children → determine appropriate interventions

THANK YOU!

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Motivation: The Learning Crisis

Lack of learning in schools presents a major concern in Sub-Saharan Africa (World Bank 2018)

- Millions complete primary education without acquiring the basic competencies
- 6th grade student regional assessment in Southern and East Africa: 37 percent are not competent in reading, and more than 60 percent are not competent in mathematics
- Drivers of learning: learner unpreparedness, teacher skills and motivation, school inputs, and school management and governance capacity
- Despite programs targeted at these constraints (Evans and Acosta, 2021), the learning crisis persists (World Bank, 2018)

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Robustness Check: Test for Residential Sorting

Table: Relationship LN [Number of Test Takers], Treatment (Lead Exposure)

	LOG OF NUMBER OF TEST TAKERS (1)
Severity of Lead Exposure	-0.03 (0.02) [0.27]
Observations (Schools, N)	2102

Notes: Represents an output of a regression as in equation (1) of the log of number of test-takers on the severity of lead exposure measure. Standard errors in parentheses; p-values in brackets.

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Robustness Check: Negative Weights Diagnostics

	RESIDUALIZED TEST SCORES
	(1)
Residualized treatment	-0.21 (0.03) [0.00]
Treatment group	0.03 (0.01) [0.00]
Treatment group \times residualized treatment	0.12 (0.33) [0.40]

Dependent variable is the residual from a regression of the standardized test scores on school and year fixed effects. Residualized treatment is the residual from a regression of the treatment dummy (an indicator for years when lead exposure occurred for schools within 4km radius of the plant) on school and year fixed effects. Standard errors in parentheses; p-values in brackets.

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Scatter Plots: Residualized Outcomes and Residualized Treatment

