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ABSTRACT

North-South Displacement Effects of Environmental Regulation: The Case of Battery Recycling*

This study examines the effect of a tightening of the U.S. air-quality standard for lead in 2009 on the relocation of battery recycling to Mexico and on infant health in Mexico. In the U.S., airborne lead dropped sharply near affected plants, most of which were battery-recycling plants. Exports of used batteries to Mexico rose markedly. In Mexico, production increased at battery-recycling plants, relative to comparable industries, and birth outcomes deteriorated within two miles of those plants, relative to areas slightly farther away. The case provides a salient example of a pollution-haven effect between a developed and a developing country.

JEL Classification: F18, Q56, O15

Keywords: pollution-haven hypothesis, environmental regulation, infant health

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I. Introduction

One of the animating concerns of the trade-and-environment debate is the idea that tighter environmental regulation in richer countries may, through trade, lead to relocation of dirty production activities to poorer countries with weaker regulations. Although not always stated, the concern often includes worries about adverse health effects in the destination. This is one articulation of what is commonly referred to as the *pollution-haven hypothesis*.

Despite the prominence of this idea in academic and policy discussions, the direct evidence that environmental regulation can displace polluting activities from developed countries (the "North") to developing countries with weaker regulations (the "South") remains thin. Several influential papers have documented displacement effects across regions within the U.S. (Henderson, 1996; Becker and Henderson, 2000; Greenstone, 2002), but there is less evidence for North-South displacement. A leading study by Hanna (2010) finds that the Clean Air Act Amendments in the U.S. increased outgoing foreign direct investment (FDI) but not disproportionately to developing countries. The reviews by Copeland and Taylor (2004), Levinson (2010), Karp (2011), Cherniwchan et al. (2017), Dechezleprêtre and Sato (2017), Cole et al. (2017), and Copeland et al. (2021) report some evidence that regulation leads to fewer exports and more imports of pollution-intensive goods and less inward and more outward FDI, but little direct evidence of displacement of pollution-intensive production from North to South.

It appears that the dominant view in the policy world is that such displacement effects, if they exist, are small and relatively innocuous. For instance, the World Bank's 2020 *World Development Report*, its flagship publication, asserts: "[E]mpirical evidence shows that strict environmental regulation of polluting industries *has not led to large relocations to countries with less-strict standards....* The association of falling trade costs and tighter environmental regulations could drive polluters to flee to developing countries. *But this has not happened*" (World Bank, 2020, p. 125, emphasis added).

Here we provide a counterexample to this anodyne view. Focusing on recycling of used lead-acid batteries (ULAB), we document a direct effect of tightened air-quality regulation in the U.S. on relocation of polluting activities to Mexico and on birth outcomes in Mexico. Battery recycling has a number of features that make it both salient and amenable to empirical study. First, the industry is an intensive emitter of lead, a particularly noxious pollutant. A recent UNICEF report lists battery recycling first among concerning sources of lead exposure for children (Rees and Fuller, 2020).[1] Lead exposure has been linked to retarded fetal growth, lower IQ, lower educational achievement, and several other adverse outcomes. Second, there was a sharp experiment: in early 2009, the U.S. tightened the National Ambient Air Quality Standard (NAAQS) for lead by a factor of 10, from 1.5 $\mu g/m^3$ to 0.15 $\mu g/m^3$; the standard in Mexico remained stable at 1.5 $\mu g/m^3$ over the period. Third, the data environment allows us to track the relocation of battery recycling. We observe the locations of battery-recycling plants in the U.S., ambient lead levels at monitoring stations nearby, ULAB trade flows from the U.S. to Mexico, industry output and the locations of ULAB recycling plants in Mexico, and birthweight of infants born to mothers who live near them, a particularly well-measured and fast-responding health outcome.

We have five main findings. First, the revised air-quality standard reduced ambient lead concentrations around U.S. battery-recycling plants. Lead concentrations declined sharply in areas where the new regulation was binding relative to areas where it was not; we estimate that the new standard reduced concentrations by 0.242 $\mu g/m^3$ from a pre-reform mean in binding areas of 0.549 $\mu g/m^3$. Second, ULAB exports from the U.S. to Mexico rose markedly after the reform; after remaining roughly constant between 2005 and 2008, ULAB exports rose by a factor of four between Jan. 2009 and the end of 2014. Third, the growth of value-added and output in Mexican battery-recycling plants was sharply higher in 2008–2013 than in 2003–2008, relative to similar industries. Value-added in battery recycling grew by 62.2% over the 5-year period from 2003–2008 (i.e. approximately 12.4% per year) and by 243.2% from 2008–2013; the comparable numbers for non-battery plants in the same broad sector (averaging across 6-digit subsectors) are 77.5% and -2.2%. Fourth, the average incidence of low birthweight increased significantly near Mexican battery-recycling plants (within 2 miles) relative to areas slightly farther away (between 2 and 4 miles). Averaging over all hospital types, we estimate that the policy change increased the incidence of low birthweight by 0.020 on a pre-reform mean of 0.095. Fifth, the health effects were concentrated among mothers in hospitals run by the Mexican Ministry of Health, who tend to be of lower socio-economic status than mothers in other hospital types. For this disadvantaged group, we estimate that the incidence of low birthweight rose by 0.048 on a pre-reform mean of 0.128 in our preferred specification; we find no statistically significant effect for mothers in private

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[1] A 2017 World Health Organization (WHO) report writes, “Lead recycling is an important source of environmental contamination and human exposure in many countries.... [T]he health impacts of lead exposure are significant... Young children, pregnant women and women of childbearing age are particularly vulnerable to the toxic effects of lead” (WHO, 2017, pp. 2–3, 14).

or other public hospitals. Together, these findings suggest strongly that the tightening of the U.S. lead regulation induced the relocation of battery recycling and caused negative health spillovers in Mexico. They also reinforce the argument of a large environmental-justice literature that the poor are disproportionately affected by environmental hazards (Currie, 2011; Hsiang et al., 2019).

We provide a short review of the literature on the displacement effects of environmental regulation in Appendix A. Our reading is that few studies using quasi-experimental designs have focused on relocation of dirty production activities from North to South, and that those few have found little evidence of such displacement. In addition, we are not aware of a study that has traced the effects of rich-country environmental regulation through to health outcomes in a destination country.

II. Background

Lead-acid batteries are a major use of lead, and much of the lead in new batteries is from recycling of used batteries. In the U.S. in 2009, for instance, nearly 90% of lead consumption was for new lead-acid batteries, and approximately 90% of refined lead production was from ULAB recycling (Guberman, 2012). Moreover, 99% or more of ULABs are typically recycled, making the lead-acid battery industry nearly a "closed loop," in which almost all lead used in production is reused in the same sector (Davidson et al., 2016).

The U.S. has made substantial reductions in lead in ambient air, reducing average airborne lead concentrations by more than 90% from 1980 to 2016 (U.S. EPA, 2014), mostly by phasing out lead in gasoline (starting in 1973) and banning lead in paint (in 1978). In Mexico, lead was largely unregulated until the early 1990s, when limits were imposed on the lead content of paints, toys, pens, cosmetics and several other products (Romieu et al., 1994).

Despite the regulatory measures, lead continues to endanger public health. It is known to affect almost every organ and system in the human body. Children under six years old and fetuses are considered most susceptible, and exposure has been linked to learning disabilities, lower IQ, lower educational achievement, and later criminal activities (Needleman et al., 1990; Reyes, 2007; Aizer et al., 2018; Billings and Schnepel, 2018; Grönqvist et al., 2020). A number of studies have documented a relationship between maternal lead levels and birth outcomes, although the precise physiological mechanisms remain unclear (González-Cossío et al., 1997; Torres-Sanchez et al., 1999; Hernández-Ávila et al., 2002; Ettinger and Wengrovitz, eds, 2010; Zhu et al., 2010; World

Health Organization, 2017; Grossman and Slusky, 2019). Over time, the level of lead exposure considered to be safe has declined dramatically. The Centers for Disease Control and Prevention (CDC) progressively lowered its "level of concern" for blood-lead levels in children from 60 $\mu g/dl$ in 1960 to 10 $\mu g/dl$ in 2002; in 2012, it stopped using the "level of concern" terminology and concluded that "no safe blood lead level in children has been identified" (CDC, 2005, 2012).

In response to the growing body of evidence, the U.S. Environmental Protection Agency (EPA) reduced the NAAQS for lead from 1.5 $\mu g/m^3$ to 0.15 $\mu g/m^3$ in early 2009. It issued an Advance Notice of Proposed Rulemaking (ANPR), opening a period of debate, on Dec. 5, 2007. The new standard was signed on May 1, 2008 and took effect on Jan. 12, 2009. The standard is applied to three-month moving averages and enforced at the level of geographical areas, typically counties. An area found in violation is assigned "non-attainment status," which opens the door to substantially more stringent regulation.[2]

In Mexico, the air-quality standard remained at 1.5 $\mu g/m^3$ throughout our study period, and other dimensions of the regulatory regime were also largely unchanged. Awareness of the dangers of lead exposure from battery recycling grew over the period due to several reports and press accounts (OKI&FC, 2011; Commission for Environmental Cooperation (hereafter CEC) 2013; Rosenthal, 2011), and new point-of-production regulation was proposed in April 2014 and took effect in January 2015 (Diario Oficial, 2014; 2015).

There exist technologies for reducing lead emissions from battery-recycling plants, including systems to filter exhaust through fabric ("baghouse systems"), to remove particles from exhaust through electrostatic precipitation, and to reduce fugitive dust emissions by enclosing production areas (CEC, 2016). But these systems are costly. For instance, Burr et al. (2011) estimate that the annual costs for reducing lead concentrations to the new NAAQS standard for 14 plants active in 2009 together was \$9.6 million per year.

One other important institutional detail is that the U.S. has not ratified the 1992 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, and ratifying countries (188 total) are in principle prohibited from trading with non-ratifying countries in the absence of a bilateral agreement. The U.S. has a bilateral agreement for export of

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[2] In 2012, the EPA also tightened a pollution standard at the point of production, the National Emission Standards for Hazardous Air Pollutants (NESHAP) for secondary lead smelting, which had been unchanged since June 1997. The new standard was implemented on January 5, 2012, and existing plants were given until January 6, 2014 to conform to the new rule (EPA, 2012). Given the timing of effects we document, we believe that the NAAQS change was the primary driver of production relocation, although the NESHAP change may have contributed in later years.

hazardous waste (which includes ULABs) only with Canada and Mexico.[3] Thus in our context, the “South” effectively means Mexico only.

III. Data

Here we briefly describe our data sources; additional details are in Appendix B. We focus on the period 2002–2015.

We identify the geocoded locations of lead-emitting plants in the U.S. using the Toxic Release Inventory (TRI). Among lead-emitting plants, we identify battery recyclers from a report by the Commission for Environmental Cooperation (CEC, 2013). The report lists 15 battery-recycling plants in the U.S., operated by 7 firms, in operation in 2007.

The EPA measures compliance with air-quality standards at approximately 4,000 monitors across the country, approximately 580 of which monitor lead. Appendix Figure A.1 plots their locations. The monitors are not located randomly: often they are placed where pollutant concentrations are expected to be high and measure the pollutants expected to be prevalent there. The monitors that measure lead tend to be located close to lead-emitting plants. We define distance for each monitor as the distance to the nearest lead-emitting plant. We focus on monitors within two miles of a lead-emitting plant, for reasons discussed below. To reduce the possibility that our estimates reflect the endogenous placement of monitors, we focus on monitors that were in place prior to the 2009 reform.[4] Appendix Table A.1 reports summary statistics for the 142 monitors in our main sample and the 22 monitors near a battery-recycling plant.

We constructed a list of 26 authorized battery-recycling plants in Mexico from CEC (2013) and from the website of the ministry overseeing the Mexican counterpart of the TRI, the *Registro de Emisiones y Transferencia de Contaminantes* (RETC). Unfortunately, airborne lead concentrations were not systematically measured outside Mexico City during our study period. The location of Mexican battery-recycling plants are plotted in Appendix Figure A.2.

The data on exports and imports are from the U.S. Census Bureau, Foreign Trade Division, available on a monthly basis. Trade of used lead-acid batteries is tracked in U.S. tariff codes 8548100540, 8548100580, and 8548102500, and we aggregate these three codes.

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[3] See CEC (2013) and the EPA summary at https://www.epa.gov/hwgenerators/international-agreements-transboundary-shipments-hazardous-waste. (Accessed July 26, 2021.)

[4] In the empirical analysis, we include monitor fixed effects to absorb time-invariant differences across monitor locations.

The Mexican production data are from the 2004, 2009 and 2014 Economic Censuses, each of which contains information from the previous calendar year. We provided lists of battery-recycling plants active in 2008 and 2013 to INEGI, the Mexican statistical agency, and INEGI staff linked them to the Census microdata. To identify plants active in 2003, INEGI used the longitudinal links compiled by Busso et al. (2018). It was possible to identify 8 battery recycling plants in 2003, 11 in 2008, and 15 in 2013.[5] Given the small number of plants, we are limited to using the censuses, rather than Mexico's monthly and annual industrial surveys, which have much less extensive coverage.

Our data on Mexican birth outcomes are from two sources. The first is discharge records of hospitals operated by the Mexican Ministry of Health (MH), which primarily serve a disadvantaged population not covered by the Mexican social security system. The data report birthweight, gestation period, mother's age, and fetal death and are available on a consistent basis for 2005–2015. The second source is birth certificates issued by the Mexican National Health System, available beginning in 2008. While they are available for only one pre-reform year, they cover the universe of births and report detailed demographic characteristics of mothers. The broader coverage allows us to compare MH hospitals to private hospitals, whose patients tend to be significantly richer, and to other public hospitals, which cover mainly formal-sector workers and their families. Both sources report locality (*localidad*) of mother's residence, corresponding roughly to neighborhood. Appendix Table A.3 presents summary statistics for the two sources. Mothers in MH hospitals are younger, less likely to be married, and have lower completed schooling than those in private or other public hospitals.

IV. Results

A. Compliance with the New Lead Standard in the U.S.

In this section, we examine the effect of the tightening of the air-quality standard on airborne lead concentrations in the U.S. Because of data constraints, two empirical strategies that might seem natural in this setting are not feasible. One would be to compare ambient lead levels at monitors near and slightly farther away from plants affected by the reform. The difficulty here is

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[5] The linking process may have missed some recycling plants in 2003 that stopped producing before 2008 Census, but this would lead us to overstate the change in production between 2003 and 2008 and hence understate the acceleration in production between 2008 and 2013.

that the number of monitors that measure lead more than two miles away from battery-recycling plants (or other lead emitters) is very limited. Another strategy would be to compare lead levels at monitors near lead-emitting plants to those near non-lead-emitting plants. The difficulty in this case is that few monitors near non-lead-emitting plants measure lead.

Given the data constraints, our strategy is to compare pollution levels at monitors near lead-emitting plants more and less affected by the regulation. We compare monitors near lead-emitting plants where the reform was binding, with ambient lead levels above 0.15 $\mu g/m^3$ prior to the reform, to monitors near lead-emitting plants where the reform was not binding. In implementing this strategy, a key decision is how to define "near." Our preferred definition is within two miles of a lead-emitting plant. As motivation for this choice, Appendix Figure A.3 plots lead concentrations by distance from plants for which average concentrations at nearby monitors were above the new standard, which we refer to as "binding" plants; the concentrations fall off quickly within the first two miles and remain roughly similar between 3 and 10 miles.[6] Below we also report results using a one-mile range, which we refer to as "very near."

Figure 1 plots average lead concentrations over time at monitors within two miles of a lead-emitting plant, separately for areas where the new standard was binding and where it was not. The vertical lines indicate the dates of the ANPR, the signing of the new standard, and the implementation of the new standard. For binding areas, there was no obvious trend pre-reform, but there was a clear decline in lead concentrations following the reform. As a further illustration, Appendix Figure A.4 plots the average lead concentration at monitors within two miles of a given lead-emitting plant in 2015 versus 2007, for plants with data in both years. Eight of the ten plants with average lead levels above the new standard in 2007 were battery-recycling plants, and all of the plants with initial average concentration levels above the new standard had average concentration levels below 0.15 $\mu g/m^3$ by 2015.

Table 1 presents simple difference-in-difference and triple-difference estimates of the effect of the reform. Columns (1)–(3) use the sample of monitors within two miles of any lead-emitting plant. The coefficient on the $Binding \times Post$ interaction in Column (1) captures the differential decline in lead concentrations at monitors where the new standard was binding relative to monitors

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[6] The WHO (2017, p. 10) reports that a California battery-recycling plant was found to have contaminated the surrounding area up to 1.7 miles away. Given that battery-recycling plants are particularly intensive lead emitters, we believe that it is reasonable to focus on a slightly larger range than the one used by a leading previous study, Currie et al. (2015), which considered a range of pollutants.

in non-binding areas.[7] The pre-reform mean at the binding monitors was 0.549 and the coefficient of -0.242 represents a decline of 44%. Column (2) shows that using an indicator for battery-recycling plant in place of the *Binding* indicator yields similar results, as would be expected given that it was mainly on such plants that the reform was binding. Column (3) adds the "very near" indicator. The coefficient on $Very\ Near \times Post \times Binding$ is identified by the comparison of the post-reform decline between monitors 0–1 and 1–2 miles from a lead-emitting plant in a binding area. The effect of the reform is statistically significantly stronger at very near monitors. At the same time, the $Binding \times Post$ interaction, which captures the effect on monitors 1–2 miles away, remains significant, providing support for our definition of "near" as within two miles. Column (4) reports the basic difference-in-difference specification for the subset of 22 monitors within 2 miles of a battery-recycling plant. The estimate is very similar to the estimate for the larger sample in Column (1). Overall, there is clear evidence that the reform reduced lead concentrations at monitors where it was binding, which were primarily those near battery-recycling plants.

It is difficult to make definitive statements about U.S. lead output from battery recycling, because confidentiality rules for the U.S. Census of Manufactures would prevent the disclosure of information for such a small number of plants. But it appears from other sources that lead production from recycling of ULABs fell over the same period. The U.S. Geological Survey reports that lead output from battery recycling fell by 13% from 2007 to 2014, from 1.1 million to .96 million metric tons (Guberman, 2009, 2016).[8] Of the 15 battery-recycling plants in operation in 2007 listed in CEC (2013), only 10 were still in operation at the end of 2014 (Guberman, 2016, 2017).[9]

B. U.S. Exports of Used Lead-Acid Batteries to Mexico

Using the trade data from the U.S. Census Bureau, Figure 2 plots monthly ULAB exports from the U.S. to Mexico and to the rest of the world, primarily Canada. There was a small increase in 2004, corresponding to the construction of a battery-recycling plant in Mexico by Johnson Controls, a major auto-parts producer. But the most notable feature of the graph is the trend break in

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[7] Standard errors are clustered at the monitor level to address the possibility of serial correlation (Bertrand et al., 2004).

[8] This decline came after output had risen by 10%, from 1.0 million to 1.1 million metric tons, between 2002 and 2007.

[9] The overall decline in output was slowed by the opening of a new Johnson Controls plant (the first new battery-recycling plant in the U.S. in 20 years) in Florence, SC, announced in June 2009.

early 2009. ULAB exports rose by a factor of four between January 2009 and the end of 2014. In Appendix C.1, we test formally for a structural break using a Quandt likelihood ratio test, and we find clear evidence of a break in May–August 2009. In Appendix C.2, we conduct a difference-in-difference analysis, comparing ULAB exports to exports in other 10-digit trade categories that map into the 3-digit sector in which battery recycling is typically considered to be located, Primary Metal Manufacturing (Sector 331 in the North American Industry Classification System (NAICS)).[10] We again find clear evidence that the reform increased U.S. ULAB exports. The fact that ULAB exports increased suggests that not all of the reduction in U.S. lead concentrations can be attributed to adoption of cleaner technologies by U.S. plants, which as noted above can be costly, especially for older plants.

C. Growth of Battery Recycling in Mexico

We turn now to the growth of battery-recycling plants in Mexico. The fact that we observe only two waves of pre-reform data limits our ability to apply synthetic-control methods (Abadie, 2021), which would otherwise be natural in this context.[11] Instead, we simply compare the growth of value-added for 2003–2008 and 2008–2013 for battery recycling and other 6-digit industries from NAICS Sector 331. To form the battery-recycling "sector," we aggregate the plants identified as battery-recycling plants. Figure 3 presents a scatterplot. Battery recycling is a clear outlier. Its value-added growth over 2003–2008 (62.2% over the 5-year period, or approximately 12.4% per year) was modest, below the median of 6-digit industries in Sector 331, and its growth over 2008–2013 (243.2%) was markedly greater than the other industries.[12] Appendix Figure A.7 presents a similar scatterplot for gross output. Growth in gross output was also high for industry 331520 ("Nonferrous Metallic Parts Molded by Casting") but, again, battery recycling's growth clearly accelerated in 2008–2013 relative to almost all other industries in the broad sector.

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[10] Plants that engage in battery recycling are typically classified in NAICS 331419, Primary Smelting and Refining of Non-Ferrous Metal (except Copper and Aluminum), although in some cases they are classified in NAICS 335910, Battery Manufacturing.

[11] Given the small number of periods, this method would match battery recycling with industries based just on the 2003–2008 change in the outcome variable (e.g. value-added); it is not clear that industries that match on this single change are compelling comparators for battery recycling.

[12] The value-added growth rates for non-battery plants reported in the Introduction were calculated by taking an unweighted average of 6-digit industries in Sector 331.

D. Infant Health in Mexico

To estimate the health effects in Mexico, we compare birth outcomes for mothers living in localities near battery-recycling plants to those for mothers living in localities slightly farther away. Consistent with our approach in the U.S., we define "near" as within two miles of a battery-recycling plant and "slightly farther away" as between two and four miles away. Appendix Figure A.8 illustrates the assignment of localities to distance bins. We focus on births to mothers residing in localities in one of these two bins.

Our preferred model is the following:

$$\begin{aligned} Health_{ijmht} &= \alpha + \beta Near_j \times Post_t + \rho X_{it} + \phi Z_{j,2005} \times Post_t \qquad (1) \\ &\quad + \mu_{mt} + \gamma_j + \lambda_{ht} + \varepsilon_{ijmht} \end{aligned}$$

where i, j, m, h, and t denote individual, locality, municipality, hospital, and year, respectively. $Health$ denotes a birth outcome, e.g. an indicator for low birthweight (< 2.5 kg) or birthweight itself. $Near$ is an indicator for mother's locality being 0–2 miles from the nearest battery-recycling plant. The $Post_t$ indicator takes the value 1 in 2009 and thereafter and 0 otherwise. The X_{it} vector contains mothers' characteristics. The $Z_{j,2005}$ vector contains initial values of locality characteristics, listed in Appendix B.6. The variables μ_{mt}, γ_j, and λ_{ht} are fixed effects for municipality-year, locality, and hospital-year. The coefficient of interest is β, which captures the differential effect of the U.S. reform on birth outcomes for mothers living in localities 0–2 miles from a battery-recycling plant relative to those living 2–4 miles away. The fact that we can control for hospital-year effects is a notable advantage over previous studies (e.g. Currie et al. (2015)), since there is extensive sorting of mothers across hospitals based on observable socio-economic characteristics and most likely on unobservable characteristics as well.

Table 2 presents estimates of equation (1). Panel A uses the Ministry of Health (MH) hospital-discharge records. These data contain limited information on mothers; X_{it} here includes only mother's age and age squared. Across columns, we include progressively richer sets of controls, using the same sample. Column (1) includes just municipality-year and locality effects, Column (2) adds the $Z_{j,2005} * Post_t$ locality controls, Column (3) adds hospital effects, and Column (4) adds hospital-year effects. The dependent variables are an indicator for low birthweight (< 2.5 kg) — the primary outcome considered in the literature (e.g. Currie et al. (2015)) and our preferred outcome — in Panel A.1 and birthweight itself in Panel A.2.[13] The results are reasonably stable across columns and consistent across outcomes. Our preferred specification is the most stringent one, Column (4), with hospital-year effects. These estimates indicate that the share of low-birthweight births mothers rose by 0.048 (i.e. 4.8 percentage points) and birthweight declined by 38.5 g on average for mothers living in a locality within 2 miles of a battery-recycling plant relative to mothers living in a locality 2–4 miles away who gave birth in the same hospital in the same year.

Panel B uses the birth certificates, which are only available for one pre-reform year but are available for all hospitals. We estimate the Panel A Column (4) specification for the different types of hospitals. To facilitate comparison we include the same covariates as in Panel A, i.e. mother's age and age squared.[14] In Column (1), for MH hospitals, the low birthweight indicator estimate is very similar to the Panel A.1 Column (4) estimate and again highly significant. The birthweight estimate is larger than the Panel A.2 Column (4) estimate — Appendix B.5 discusses differences in the data sources that give rise to this difference in magnitudes — but is again negative and highly significant. Pooling across hospital types, we see an increase of 0.02 in the incidence of low birthweight on average. But this effect is driven entirely by the MH hospitals. Strikingly, there is little evidence of a negative impact on birth outcomes in other public or private hospitals. For the low birthweight indicator, the estimates for other public and private hospitals are both very close to zero. For birthweight, the point estimate for other public hospitals is in fact positive, although not statistically significant, and the point estimate for private hospitals, although negative, is an order of magnitude smaller than the estimate for MH hospitals, and again not statistically significant.

To illustrate the timing of the impacts, Appendix Figure A.9 plots coefficients from a specification similar to our preferred one, Table 2 Panel A.1 Column (4), but interacting $Near$ with dummies for each year (with 2008 as the omitted reference year). There was no obvious trend prior to 2009; to the extent that there is a pattern, it suggests that the incidence of low birthweight was declining in areas closer to battery-recycling plants. But there is an evident and statistically significant increase in 2009. We cannot reject that the effect is constant thereafter. As mentioned above, awareness of the health consequences of battery recycling increased in Mexico over the

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[13] Appendix Tables A.5–A.6 report all coefficients for the Panel A regressions, and include an additional specification with municipality controls in place of municipality-year effects.

[14] Appendix Tables A.11 and A.12 report all coefficients for the Panel B regressions. Regressions using a richer set of mothers' characteristics are reported in Appendix Tables A.13 and A.14. The results are very similar.

period, culminating in new regulation imposed in early 2015; public pressure may be in part responsible for the slight decline in the effect over 2010–2015.

We have also considered the effects on other outcomes, in particular the incidence of very low birthweight (<1.5 kg), the length of gestation period, the incidence of premature birth (<37 weeks), and the probability of live birth. Appendix Tables A.7–A.10 report the results for the MH hospital-discharge data.[15] For very low birthweight (a rare occurrence), the effect is marginally significant in our preferred specification, but not robust across specifications. We do not find robust effects on gestation length, the incidence of premature birth, or the probability of live birth. The latter result suggests that selection into birth is not a major source of bias in our main estimates.

Our estimates for birth outcomes in Ministry of Health hospitals — an 0.048 (4.8 percentage point) increase in the incidence of low birthweight and a 38.5 gram (1.3%) decline in birthweight in our preferred specification — are large relative to many existing estimates of the effect of pollution on infant health, but not out of line with evidence on concentrated exposure among disadvantaged populations. Two leading related studies find comparatively small effects. Currie and Schmieder (2009) relate U.S. firms' self-reported releases of lead in the TRI to infant health outcomes at the county level, and find that a one-standard-deviation increase is associated with just a 0.00002 increase in the incidence of low birthweight and a decline in birthweight of 0.9 g. Currie et al. (2015) consider the effects of openings of industrial plants (which emit lead and other pollutants) on births to mothers living within 1 mile and find an increase in low-birthweight incidence of 0.002 and a decline in birthweight of 3.9 g. But other recent studies have found larger effects. Currie and Walker (2011) find that the introduction of E-ZPass in New Jersey and Pennsylvania was associated with a reduction of low-birthweight incidence of approximately 0.01 for mothers living within 2 miles of toll plazas, with a larger reduction for African-American mothers (0.024). Both estimates are about half the size of ours (0.02 on average for all hospitals, and 0.048 for disadvantaged mothers in MH hospitals). A study of the switch to a contaminated water source (containing lead and other pollutants) in Flint, Michigan, estimates a 175 g (5.4%) decrease in birthweight after adjusting for selection into birth (Grossman and Slusky, 2019). Currie et al. (2009) find that reductions of carbon monoxide in some areas of New Jersey were associated with birthweight increases of approximately 60 g, roughly what would be expected for a mother going

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[15] The probability of live birth cannot be examined in the birth-certificate data, since they only record live births.

from 10 cigarettes a day to zero. The fact that our estimates are on the high side of the range of existing estimates may be explained by the facts that battery-recycling plants are particularly intensive emitters, that lead is a particularly toxic pollutant, and that mothers in MH hospitals are a particularly vulnerable population, with limited access to high-quality health care.

V. Conclusion

This short paper has provided evidence that the 2009 tightening of the U.S. airborne lead standard led battery recycling to shift from the U.S. to Mexico and negatively affected infant health near Mexican battery-recycling plants. The data have limitations: for instance, we are not able to track year-to-year changes in output of Mexican battery-recycling plants, nor are air-monitor data on lead available outside of Mexico City over the study period. But the findings provide reasonably strong evidence of a pollution-haven effect in this industry, with adverse health consequences in the destination. The fact that the health impacts are concentrated among disadvantaged mothers echoes the findings of the environmental-justice literature that the costs of environmental hazards are disproportionately borne by the poor (Currie, 2011; Hsiang et al., 2019).

Two important questions remain unanswered and merit further investigation. First, what were the health effects in the U.S. of the policy change? As noted above, two leading studies, Currie and Schmieder (2009) and Currie et al. (2015), suggest that the positive impact on U.S. birth outcomes was likely small. But neither study focuses specifically on the link between airborne lead concentrations and infant health. In addition, people living near "binding" plants tend to be disadvantaged relative even to people near other lead-emitting plants.[16] Given the income gradient in effects of pollution, one might reasonably expect larger impacts on the vulnerable population living near U.S. battery recyclers.

Second, to what extent is the case of battery recycling representative of broader patterns? We have focused on the case because there was a sharp regulatory change and a conducive data environment, but the technological characteristics of the sector may be special. Ederington et al. (2005) argue that evidence for pollution-haven effects has been mixed in part because industries with high pollution-abatement costs tend to be less mobile than those with lower costs. Battery recycling may be an unusual case in which abatement costs are high and both inputs

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[16] Appendix Table A.15 reports summary statistics from the American Community Survey indicating that the former group has lower household income and educational attainment and is much more likely to be Hispanic. See Appendix D for details.

(used batteries) and output (lead) are relatively transportable. More research on North-South displacement in other sectors is needed. But at a minimum, the case of battery recycling provides a clear example that environmental regulation in the North *can* displace polluting activities to the South.

From a policy perspective, a key contribution of this paper is to document an environmental production externality between the U.S. and Mexico — a particular sense in which the environmental fates of the two countries are linked. The externality points to a need for greater North-South coordination of environmental policy, in the same way that terms-of-trade externalities provide a motivation for trade agreements (Bagwell and Staiger, 2004). Such coordination is sure to be complicated both by differences in bargaining power between countries and by unequal distribution of impacts and influence within countries. There are also important questions about the extent to which trade and environmental negotiations should be linked (Copeland and Taylor, 2004; Limão, 2005). But it seems clear that North-South displacement effects make environmental policy a legitimate subject for North-South policy negotiations.

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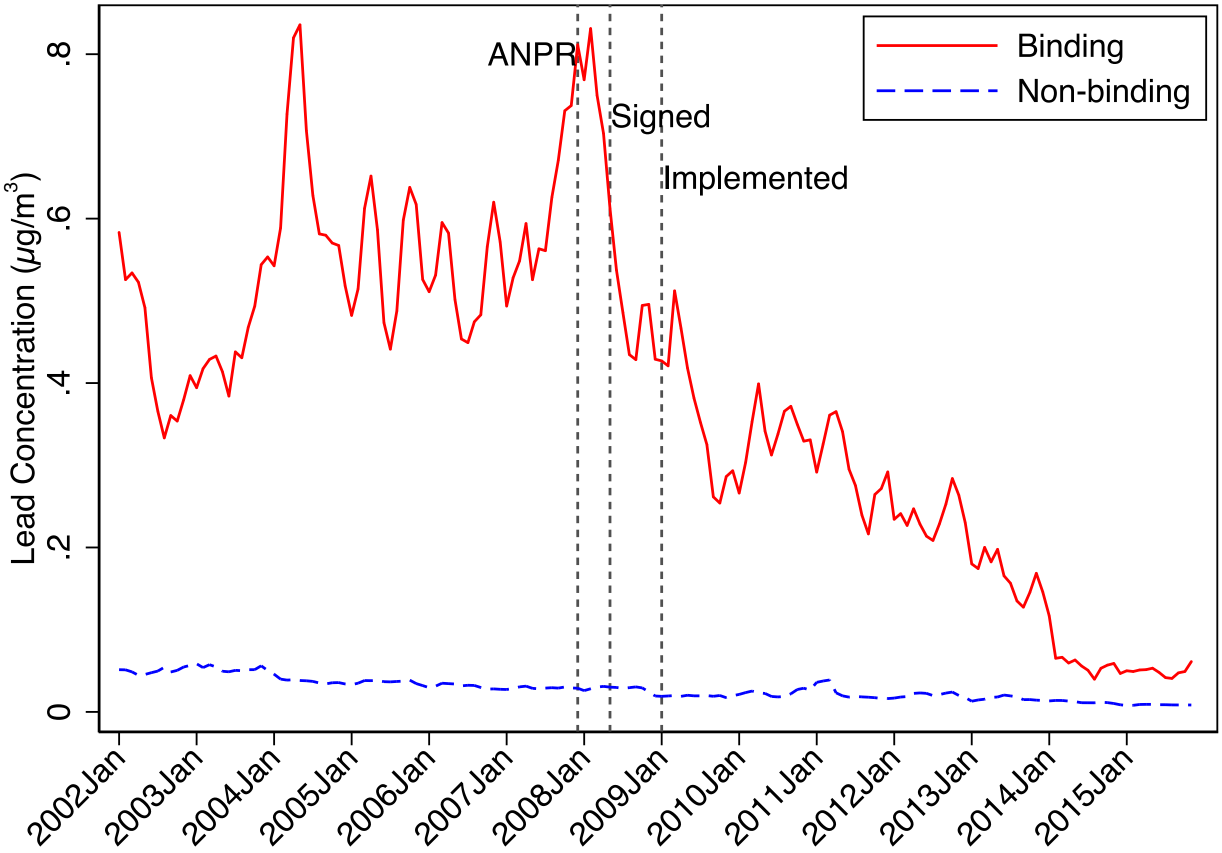
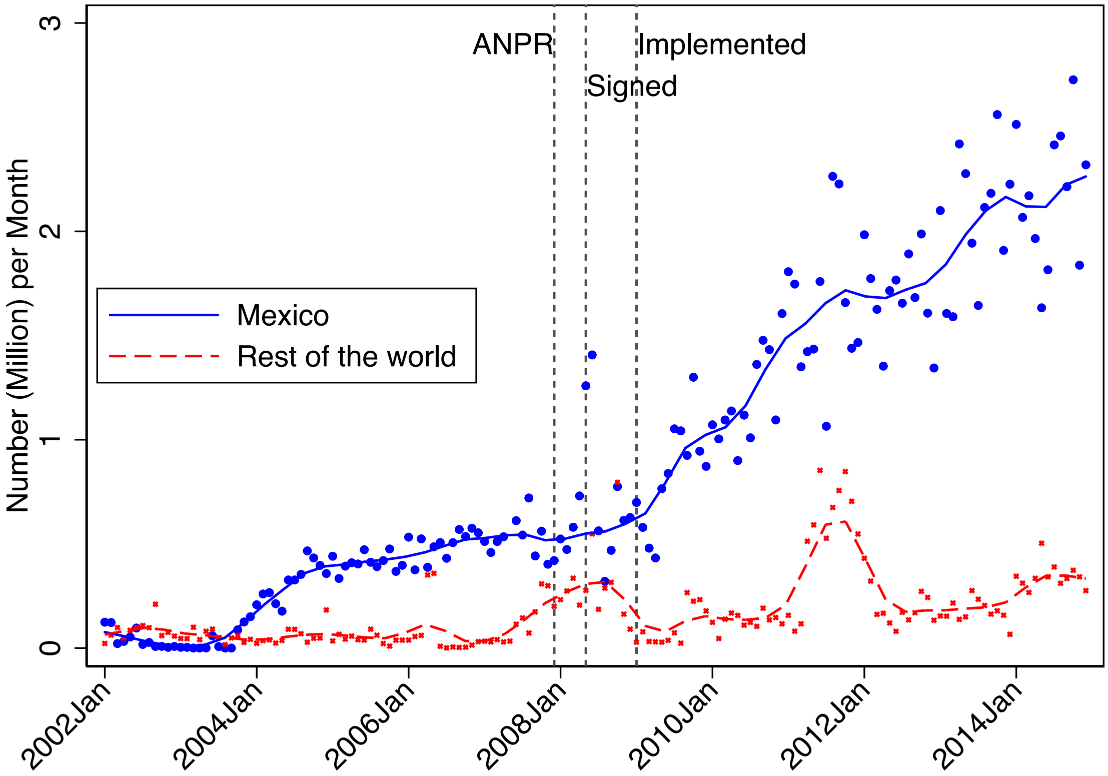
Figure 1. Lead Concentrations in U.S., Binding vs. Non-Binding Areas



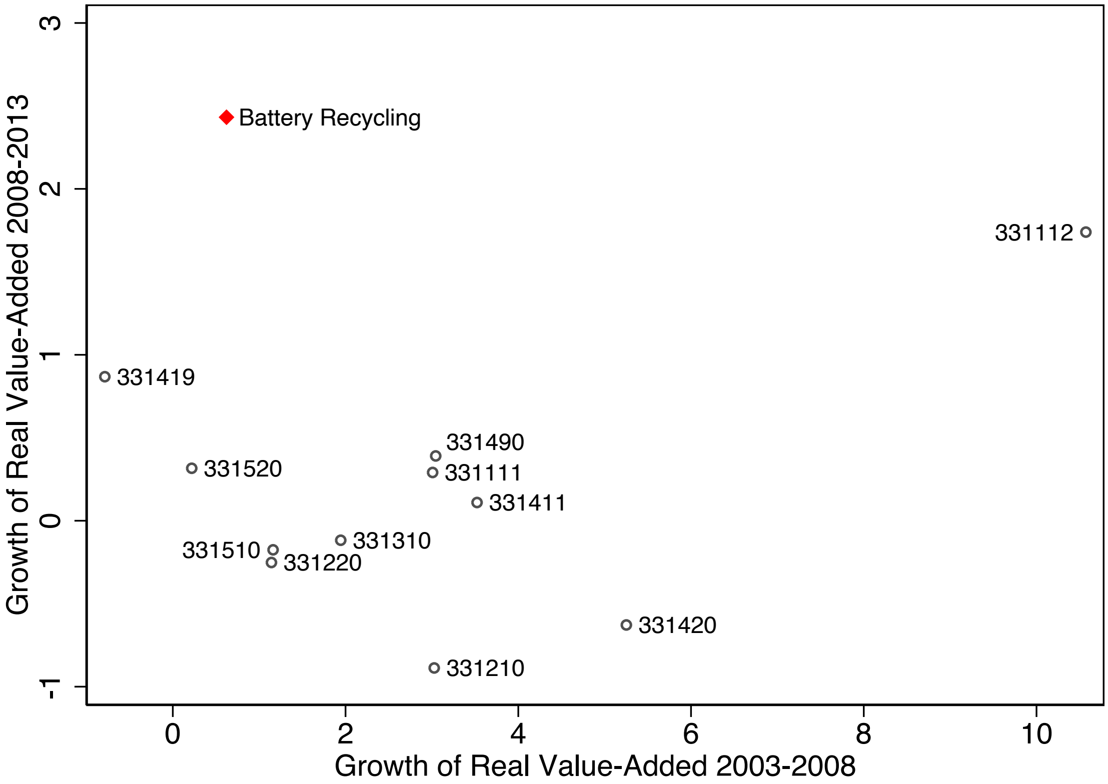
Notes: Sample is monitors within two miles of a lead-emitting plant for which we observe both pre-reform and post-reform lead concentrations. Figure plots three-month moving averages in lead concentration levels in ambient air at monitoring stations between 2002 and 2015, separately for binding areas (concentration $> .15\ \mu g/m^3$ pre-2008) and non-binding areas. The leftmost vertical line indicates the date of the Advance Notice of Proposed Rulemaking (ANPR), December 5, 2007; the middle line the signing of the revised standard (NAAQS), May 1, 2008; the rightmost the implementation of the new standard, January 12, 2009.

Figure 2. U.S. Monthly Exports of Used Lead-Acid Batteries



Notes: Each dot indicates monthly exports (measured in millions of batteries) from the U.S. to Mexico (in blue) and the rest of the world (in red). The fitted trend lines indicate smoothed local polynomial trends with the bandwidth of three months. The leftmost vertical line indicates the date of the Advance Notice of Proposed Rulemaking (ANPR), December 5, 2007; the middle line the signing of the revised standard (NAAQS), May 1, 2008; and the rightmost line the implementation of the new standard, January 12, 2009. The trend for Mexico omits May and June, 2008, just after the new standard was signed, when exports spiked temporarily. Source: U.S. Census Bureau Foreign Trade statistics. Exports are the sum for U.S. tariff codes 8548100540, 8548100580, and 8548102500.

Figure 3. Value-Added in Battery Recycling vs. Similar Industries in Mexico



Notes: Value-added by industry is from 2004, 2009, and 2014 Mexican Economic Censuses (data for 2003, 2008, and 2013), for North American Industry Classification System (NAICS) sector 331 (Primary Metal Manufacturing) and for plants identified as battery recyclers. Real value-added is defined as gross output minus intermediate input consumption, deflated by the Mexican CPI. Growth of real value-added is defined as $(va_t - va_{t-1})/va_{t-1}$. The 6-digit industries are: 331111 – Iron and steel mills; 331112 – Primary roughs and ferroalloy manufacturing; 331210 – Iron and steel pipe and tube manufacturing; 331220 – Other iron and steel product manufacturing; 331310 – Aluminum production; 331411 – Copper smelting and refining; 331412 – Precious metals smelting and refining; 331419 – Other nonferrous metals smelting and refining; 331420 – Secondary lamination of copper; 331490 – Secondary lamination of other nonferrous metals; 331510 – Iron and steel parts molded by casting; 331520 – Nonferrous metallic parts molded by casting.

Table 1. Effect of Tightened Lead Standard on Airborne Lead in the U.S.

	Dep. var.: Lead concentration ($\mu g/m^3$)			
	Monitors near lead-emitting plants			Monitors near battery-recycling plants
	(1)	(2)	(3)	(4)
Binding × Post	-0.242***		-0.142***	-0.252***
	(0.047)		(0.003)	(0.067)
Battery × Post		-0.165***		
		(0.050)		
Very Near × Post			-0.020***	
			(0.007)	
Very Near × Post × Binding			-0.102**	
			(0.050)	
N (observations)	16,858	16,858	16,858	3,133
N (monitors)	142	142	142	22
Pre-Reform Mean (binding monitors)	0.549	0.549	0.549	0.506
Monitor Effects	Y	Y	Y	Y
Year-Month Effects	Y	Y	Y	Y

Notes: "Near" is defined as $\leq$ 2 miles. Sample in Columns (1)–(3) is monitors near any lead-emitting plant. Sample in Column (4) is monitors near a battery-recycling plant. In all columns, monitors are included only if they report lead emissions both before and after January 1, 2009. Data are for 2002–2015. "Binding" means that lead concentration levels were above new standard at the most recent reading prior to January 2009. "Post" takes the value 0 prior to January 2009 and 1 thereafter. "Battery" means near a battery-recycling plant. "Very near" means $\leq$ 1 mile from a lead-emitting plant. Pre-reform mean is calculated for available years prior to 2009. Robust standard errors, clustered at the monitor level, are in parentheses. *10% level, **5% level, ***1% level.

Table 2. Effects on Birthweight in Mexico

Panel A. Hospital-Discharge Records

	Ministry of Health (MH) Hospitals			
	(1)	(2)	(3)	(4)
1. Outcome: 1(Birthweight < 2.5 kg)				
Near*Post	0.022***	0.043***	0.049***	0.048***
	(0.0081)	(0.011)	(0.012)	(0.011)
Pre-Reform Mean (Near=1)	0.128	0.128	0.128	0.128
2. Outcome: Birthweight (grams)				
Near*Post	-35.0***	-32.3**	-40.4**	-38.5**
	(10.2)	(16.0)	(16.2)	(16.3)
Pre-Reform Mean (Near=1)	3006.6	3006.6	3006.6	3006.6
Observations	319165	319165	319165	319165
Locality Effects	Y	Y	Y	Y
Municipality-Year Effects	Y	Y	Y	Y
Locality Chars.*Post	N	Y	Y	Y
Hospital Effects	N	N	Y	N
Hospital-Year Effects	N	N	N	Y

Panel B. Birth-Certificate Data

	Hospital Type			
	MH (1)	Other public (2)	Private (3)	All (4)
1. Outcome: 1(Birthweight < 2.5 kg)				
Near*Post	0.052***	0.0020	0.0024	0.020**
	(0.014)	(0.019)	(0.015)	(0.0081)
Pre-Reform Mean (Near=1)	0.124	0.100	0.071	0.095
2. Outcome: Birthweight (grams)				
Near*Post	-71.5***	28.6	-8.19	-23.5
	(23.6)	(33.4)	(27.7)	(17.4)
Pre-Reform Mean (Near=1)	3011.4	3078.8	3095.1	3068.3
Observations	226458	187684	139818	553960
Locality Effects	Y	Y	Y	Y
Municipality-Year Effects	Y	Y	Y	Y
Locality Chars.*Post	Y	Y	Y	Y
Hospital-Year Effects	Y	Y	Y	Y

Notes: Table reports 16 separate regressions. Post indicates year≥2009. All include a quadratic in mother's age; locality fixed effects (locality is area smaller than municipality); interactions of Post indicator with locality characteristics (share of households with access to water, electricity, and sewer, share of population below age 5, log total population, and share of population with social security); and interactions of Post with indicators for 1–5, 6–10, or ≥ 11 other lead-emitting plants ≤ 2 miles from mother's residence locality. Panel A sample is live births in Ministry of Health (MH) hospitals with mother's residential locality ≤ 4 mi. from battery-recycling plant, 2005–2015. Panel B sample is selected similarly but from birth certificates for 2008–2015, for MH, other public, and private hospitals. "Near" equals 1 if mother's locality is ≤2 mi. from battery-recycling plant, 0 otherwise. Pre-reform means are for near localities over available years (2005–2008 in Panel A, 2008 in Panel B). See Appendix B.6 for details on locality characteristics. Panel B uses specification from Panel A, Column (4), and varies sample. Robust standard errors, clustered at the locality level, are in parentheses. *10% level, **5% level, ***1% level.

North-South Displacement Effects of Environmental Regulation: The Case of Battery Recycling

Shinsuke Tanaka   Kensuke Teshima   Eric Verhoogen

Online Appendix

Aug. 2021

A Literature Review

The term "pollution-haven hypothesis" is often applied to two related but distinct causal mechanisms: (1) for a given level of trade barriers, changes in environmental regulation lead to relocation of polluting activities; and (2) for a given level of environmental regulation, changes in trade barriers lead to such relocation. Copeland and Taylor (2004), Cherniwchan et al. (2017), and Copeland et al. (2021) usefully give different names to the two phenomena, and refer to (1) as the pollution-haven *effect* and reserve the term pollution-haven *hypothesis* for (2). In this paper, and in this brief review of the literature, we focus on the first mechanism.[1]

Early work on this effect, reviewed by Jaffe et al. (1995), was predominantly based on cross-sectional analyses, with little explicit attention to causal identification, and generally found little evidence that environmental regulation causes displacement of polluting activities.[2]

Subsequent papers have differed in how they have addressed the possibility of omitted variables correlated both with indicators of environmental stringency and with FDI flows, trade, or other indicators of performance. One simple strategy has been to assume that such omitted variables are constant within regions or sectors and include region or sector fixed effects. Keller and Levinson (2002) include state fixed effects and show that pollution abatement costs are associated with lower inward FDI in the U.S. Controlling for industry effects, Eskeland and Harrison (2003) consider the relationship between pollution abatement costs both on FDI inflows into several developing countries (Mexico, Morocco, Ivory Coast, and Venezuela) and on FDI outflows from the U.S., finding mixed results. Chung (2014) controls for sector and destination fixed effects and shows that outbound FDI from South Korea in polluting industries was disproportionately responsive to environmental regulation (measured by responses to a survey of business executives). Using self-reported data of multinational corporations' CO_2 emissions in different countries, Ben-David et al. (forthcoming) find that greater environmental stringency in companies' home countries (measured by surveys of business executives) are associated with greater emissions abroad.

Another strategy has been to construct instruments for pollution abatement costs. Using U.S. data, Levinson and Taylor (2008) construct one instrument using a sector-level weighted average of emissions by other sectors in states where a particular sector is active, and another using a weighted average of incomes per capita, which are presumed to affect the demand for a clean environment (and hence, indirectly, pollution abatement costs). They find that increased abatement costs in the U.S. led to increases in net imports. Kellenberg (2009) uses agricultural-sector characteristics in a given country and agricultural- and manufacturing-sector characteristics in other countries as instruments for government policies, in order to estimate the effects of those policies on outbound FDI from the U.S. He also finds evidence for a displacement effect

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[1] For broader reviews of the literature, see Copeland and Taylor (2003, 2004), Brunnermeier and Levinson (2004), Levinson (2008, 2010), Cole et al. (2017), Dechezleprêtre and Sato (2017), and Cherniwchan et al. (2017).

[2] Ederington et al. (2005) pointed out that part of the reason for the lack of evidence for displacement was the failure to distinguish between strong- and weak-regulation trading partners and between more- and less-footloose industries.

of environmental regulation. Cole and Elliott (2005) use lagged pollution abatement costs as an instrument for current abatement costs and also include sector fixed effects to examine effects on outbound U.S. FDI to Mexico and Brazil.[3] The preponderance of evidence in these studies suggests that more stringent environmental regulation is associated with lower net FDI inflows (equivalently, greater net outflows). At the same time, in these studies it has not been entirely clear what is driving the variation in pollution abatement costs or in the instruments constructed for them, and concerns about possible omitted variables have persisted.[4] In addition, with the exceptions of Eskeland and Harrison (2003) and Cole and Elliott (2005), these studies have not focused explicitly on North-South displacement effects.

Another set of papers, closer in spirit to the current study, has used quasi-experimental research designs exploiting discrete, observable changes in environmental regulation. Several studies have focused on displacement effects of the Clean Air Act within the U.S., generally finding significant effects (Henderson, 1996; Becker and Henderson, 2000; Greenstone, 2002). Najjar and Cherniwchan (2021) and Cherniwchan and Najjar (forthcoming) focus on a similar set of regulations in Canada and find that tighter regulation reduced exports. But few papers in this set have focused explicitly on displacement from North to South. Hanna (2010) finds displacement effects of Clean Air Act Amendments on outbound FDI but not displacement to the South. Cai et al. (2016) examine the effect of differential tightening of environmental regulations across cities in China on inbound FDI, and find a negative investment response from countries with weaker environmental protections than China but not from countries with stronger protections.

Recent papers by Aldy and Pizer (2015) and Fowlie et al. (2016) have estimated the effects of energy prices on output and net imports at the sector level in the U.S. and have found some evidence that higher energy prices in the U.S. (and in the case of Fowlie et al. (2016), lower foreign energy prices) lead to greater net imports. This work has mainly aimed to inform the design of cap-and-trade regulation in the U.S. and has not directly analyzed outcomes in the U.S.'s trading partners, nor focused on whether displacement (or "leakage") occurs particularly to countries with weaker regulations.

Overall, as we note in the main text, our reading of the literature on the displacement effects of environmental regulation is that there have been few studies using quasi-experimental designs that have focused on relocation of dirty production activities from North to South, and these few have found little evidence for North-South displacement.

Our paper is also related to a small strand of literature on trade of used or waste goods.

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[3] In a cross-country study, Aichele and Felbermayr (2012) examine the effects of the Kyoto agreement. They instrument participation in the agreement by participation in the International Criminal Court and find that participation in Kyoto reduces domestic carbon emissions and increases emissions embodied in imports. In related work, Broner et al. (2013) instrument environmental regulation by meteorological determinants of pollution dispersion and find that countries with weaker regulation have relatively higher import shares in the U.S. market.

[4] For instance, in their review, Cherniwchan et al. (2017) write: "One issue with the [Levinson and Taylor (2008) and Kellenberg (2009)] is that they rely on research designs that employ model-based arguments for identification. This makes it difficult to ensure that the resulting estimates are causal; if the theoretical model is misspecified, it is likely that corresponding identification assumptions will not hold."

Levinson (1999) finds that the U.S. states that increased hazardous waste disposal taxes experienced decreases in hazardous waste shipments from other states. Kellenberg (2012) finds that international waste trade flows are affected by the relative stringency of environmental standards of trading countries. Davis and Kahn (2010) find evidence for a pollution-haven hypothesis on the consumption (rather than production) side: the liberalization of automobile trade under NAFTA induced the movement of used cars from the U.S. to Mexico, increasing pollution overall by keeping cars on the road longer. A volume edited by Kojima and Michida (2013) collects several relevant papers on trade of waste products.

Finally, our paper contributes to the literature on the consequences of lead exposure. As noted in the main text, health economists have found that lead exposure can affect various outcomes such as academic achievement and crime; see e.g. Reyes (2007), Nilsson (2009), Aizer et al. (2018), Rau et al. (2015), Billings and Schnepel (2018), and Grönqvist et al. (2020). Much of the health-economics literature focuses on developed countries, with the exception of Rau et al. (2015), who analyze a case from Chile. This paper thus contributes to the broader research program of comparing pollution effects on health in developed and developing countries (Arceo et al., 2016). We also contribute to a small health literature on the effects of lead exposure on birth outcomes (González-Cossío et al., 1997; Hernández-Ávila et al., 2002; Ettinger and Wengrovitz, eds, 2010; Grossman and Slusky, 2019). For reviews of the literature on pollution and infant health, see Currie (2011, 2013), Graff Zivin and Neidell (2013), and Currie et al. (2014).

As noted in the main text, we are not aware of a study that has traced the effect of environmental regulation in a developed country through to health outcomes in a developing country. The only other paper we are aware of that explicitly links trade and health through the environment is Bombardini and Li (2020), which analyzes the impact of export-market access on the environment and child mortality in China.

Battery recycling has been the subject of studies by non-governmental organizations (OKI&FC, 2011), governmental commissions (CEC, 2013; WHO, 2017), the popular press (Noyes, 1990; Rosenthal, 2011), and environmental health researchers (Gottesfeld and Pokhrel, 2011; Turner, 2015), but we are not aware of a systematic study in the economic literature.

B Data Appendix

This appendix provides additional details for datasets described in Section III of the main text.

B.1 U.S. Toxic Release Inventory

U.S. Toxic Release Inventory (TRI) emissions are self-reported and are known to suffer from substantial errors (de Marchi and Hamilton, 2006; Koehler and Spengler, 2007). We therefore follow Currie et al. (2015) and use the TRI only to identify emitters and their locations, without relying on the reported amount of emissions.

B.2 Locations of Mexican Battery-Recycling Plants

Mexican plants in specified industries that emit particular chemical substances are legally obliged to register in the Mexican counterpart of the TRI, the *Registro de Emisiones y Transferencia de Contaminantes* (RETC, Registry of Emission and Transfer of Pollutants), every year. The ministry that oversees is the *Secretaría de Medio Ambiente y Recursos Naturales* (SEMARNAT, Ministry of Environment and Natural Resources). We accessed the ministry's list of authorized battery-recycling plants on Dec. 30, 2011.[5] The url is no longer active. The exact locations of the authorized plants were identified from the RETC and SEMARNAT lists and CEC (2013), as well as supplementary online searches. There may have been plants that recycled batteries without authorization that do not show up on any of the lists; these will not enter into our analysis.

B.3 Pollution Measurement in Mexico

As mentioned in Section III, airborne lead concentrations were not systematically measured outside Mexico City during our study period. Although there were monitors that measured lead in the Mexico City metropolitan area (see e.g. Davis (2008) and Hanna and Oliva (2015)), the coverage was much reduced outside of Mexico City (Commission for Environmental Cooperation, 2013). The national system of air-quality monitors, the *Sistema Nacional de Información de la Calidad del Aire (SINAICA)*, does not report lead concentrations. Satellite data, used for instance by Foster et al. (2009) and Gutiérrez and Teshima (2018), are not able to distinguish between lead and other pollutants, nor are they available at the fine level of geographic disaggregation that our approach would require.

B.4 U.S. Exports to Mexico

The U.S. export data are from U.S. Census Bureau data on monthly commodity flows between 2002 and 2015. In the U.S. Harmonized Tariff Schedule, the 6-digit category 854810 refers to "Waste and scrap of primary cells, primary batteries and electric storage batteries; spent primary cells, spent primary batteries and spent electric storage batteries." The 8-digit category 85481005 refers to "Spent primary cells, spent primary batteries and spent electric storage batteries, for recovery of lead." The 10-digit category 8548100540 refers to "Lead-acid storage batteries, of a kind used for starting engines," and 8548100580 to "other" cells and batteries. The 10-digit category 8548102500 refers to items in 854810 but not in 85481005 that are used for recovery of lead. In principle, spent batteries should be in 8548100540 or 8548100580, but the CEC report notes, based on interviews with industry participants, that 8548102500 is also often used for spent lead-acid batteries (CEC, 2013) and so we include it as well.[6] We have corrected the raw reported

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[5] Url: http://tramites.semarnat.gob.mx/images/stories/menu/empresas/rubro1.pdf

[6] One might ask whether it would be possible to link U.S. exports of used lead-acid batteries (ULABs) directly to Mexican battery-recycling plants, using customs records as in Sugita et al. (2021). Unfortunately, it appears that battery recyclers typically do not import the ULABs directly and hence do not show up in the customs records.

values using commodity-specific statistical corrections provided by the Census Bureau. Numerous corrections were reported for years around 2009 for ULAB exports to Mexico. After incorporating the Census Bureau corrections, the export figure for May 2007 remains a clear outlier and we have dropped it.

B.5 Birth Outcomes in Mexico

B.5.1 Ministry of Health Hospital-Discharge Records

The hospital-discharge records were downloaded from the website of the Mexican *Secretaría de Salud* (Ministry of Health)[7] in two stages, for 2005–2013 on July 21, 2015, and for 2014–2015 on July 15, 2018. The data are no longer accessible at the website.

Birthweight, gestation period, mother's age and locality of residence are available on a consistent basis for the 2005–2015 period. A few reported birthweights are below 250 g (the lowest-ever recorded birthweight for a live birth); we assume these are errors and drop the observations. The bottomcoding of birthweight varied over time; to maintain consistency across years, we bottomcode at 501 g throughout the study period. To further reduce the influence of outliers, we "winsorize" the birthweight and gestation period variables for live births at the 1st and 99th percentiles (setting values below the 1st percentile to the 1st percentile value, and values above the 99th percentile to the 99th percentile value). For mother's age, we assume that ages below 10 or above 50 are errors and drop the observations. Using the birthweight variable, we construct indicators for low birthweight (<2.5 kg) and very low birthweight (<1.5 kg). Using the gestation period variable, we construct an indicator for premature birth (<37 weeks).

Our econometric strategy is to compare births to mothers residing in localities near battery-recycling plants (0–2 mi.) to those slightly farther away (2–4 mi.), controlling for municipality-year effects. We therefore drop all births to mothers residing in localities more than 4 miles from a battery-recycling plant. We only include observations with complete information on the mother and birth characteristics listed above and the locality and municipality characteristics listed below in Section B.6. Summary statistics on the estimation sample are in Columns (1)–(2) of Appendix Table A.3.

B.5.2 Birth Certificates

The Mexican National Health System (*Sistema Nacional de Salud)* only began issuing birth certificates in September 2007, when it became a legal mandate, and the data are available only since 2008. Previously, the only birth records available in Mexico were issued by civil registries and contained no information on infant health or mothers' demographics. The birth-certificate data were also downloaded from the Ministry of Health website in two stages, for 2008–2013 on

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[7] Url: http://www.dgis.salud.gob.mx/contenidos/basesdedatos/std_egresoshospitalarios.html.

July 21, 2015, for 2014 on Dec. 1, 2017, and for 2015 on July 15, 2018.[8] The data are no longer accessible at the website.

The following variables are available:

- *Birthweight.* Weight at birth in grams.
- *Gestation period.* Length of pregnancy in weeks.
- *Mother's age.*
- *Mother's marital status.* Takes on values married, single (never married), divorced, widowed, in a civil union, separated, unspecified, and unknown. We re-code into five categories: married, single, divorced/widowed/separated, in civil union, and other.
- *Parity.* Takes values 1–25 or "unspecified."
- *Number of live births.* Takes values 1–25 and unspecified. We re-code this variable into three categories: 1st live birth, 2nd live birth, more than 2nd live birth.
- *Condition of previous pregnancy.* Takes values alive, dead, no previous pregnancy, and unknown.
- *Antenatal care.* Takes value 1 if mother received prenatal care, 0 otherwise.
- *Mother's education.* Categorical variable for none, primary incomplete (from 1 to 5 years), primary complete, secondary incomplete, secondary complete, high school incomplete, high school complete, professional, and unknown.
- *Mother's locality of residence.*

The data also report the type of institution in which the birth occurred, which we code into four categories: (1) Ministry of Health hospitals; (2) other public hospitals, which include those affiliated with the *Instituto Mexicano del Seguro Social (IMSS)*, *Instituto de Seguridad y Servicios Sociales de los Trabajadores del Estado (ISSSTE)*, *Petróleos Mexicanos (PEMEX)*, the state-run oil company, the Mexican Ministry of National Defense (SEDENA), the Ministry of the Navy (SEMAR), and other public units; (3) private hospitals; and (4) other places, including public places, homes, and "unspecified." We focus on hospital births and drop births in the fourth category.

We process the birth-certificate data similarly to the hospital-discharge records. We assume that reported birthweights for live births below 250 g are errors and drop the observations. Birthweight was topcoded at 6 kg in 2012–2015 and at 7 kg in other years; to maintain consistent topcoding, we impose the 6 kg topcode in all years. To further reduce the influence of outliers,

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[8] Urls: http://www.sinais.salud.gob.mx/basesdedatos/std_nacimientos.html and http://www.dgis.salud.gob.mx/contenidos/sinais/subsistema1.html.

we "winsorize" the birthweight and gestation period variables for live births at the 1st and 99th percentiles. For mother's age, we assume that ages below 10 or above 50 are errors and drop the observations. Using the birthweight variable, we construct indicators for low birthweight (<2.5 kg) and very low birthweight (<1.5 kg). Using the gestation period variable, we construct an indicator for premature birth (<37 weeks).

As in the hospital-discharge records, we limit the sample to births to mothers residing in localities within 4 miles of a battery-recycling plant. We only include observations with complete information on the mother and birth characteristics listed above and the locality and municipality characteristics listed below in Section B.6. Summary statistics on the estimation sample are in Columns (3)–(8) of Appendix Table A.3.

A word of explanation is in order on the comparison between the Ministry of Health hospital-discharge data and birth-certificate data from Ministry of Health hospitals. In principle, the subset of births in Columns (1)–(2) for the years 2008–2015 should correspond exactly to the set of births in Columns (3)–(4). Indeed, the raw number of live births are quite similar in these years. But there are two notable differences in the datasets. First, on a significant share of birth certificates (∼5–10%), birthweight is not recorded; we drop these observations. Second, the birth certificates record a more disaggregated set of birthplaces, including satellite clinics associated with Ministry of Health hospitals; for that reason, the number of hospitals is larger in the birth-certificates data. There are also small differences in the way the institutions process data, for instance in top-coding and bottom-coding. The means reported in Appendix Table A.3 are very similar, but the differences in years, in data processing, and in the samples that survive our cleaning process give rise to differences in the regression results in Table 2.

B.6 Locality and Municipality Characteristics

Locality (*localidad*) is a geographical designation below municipality but above block (*manzana*) and basic statistical area (*AGEB*) in the Mexican geographical classification system. It corresponds roughly to neighborhood. We take the longitude and latitude of each locality from INEGI's catalog of geostatistical areas (*Archivo Histórico de Localidades Geoestadísticas*).

The following locality characteristics are taken from the locality-level statistics of a 2005 population enumeration (*El Conteo de Población y Vivienda 2005*) reported by INEGI.[9]

- *Water access.* Share of households in locality with access to public water services.
- *Electricity access.* Share of households in locality with access to electricity.
- *Sewer access.* Share of households in locality with access to sewerage.
- *Young population.* Share of population in locality aged 5 and below.

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[9] The locality-level statistics were downloaded from url https://www.inegi.org.mx/contenidos/programas/ccpv/2005/datosabiertos/cpv2005_iter_00_csv.zip on Feb. 9, 2021. Enumerations are conducted every 10 years, between decennial population census, in years ending in 5.

- *Population.* Total population of locality.
- *Social security.* Share of population in locality covered by a social security agency (Spanish acronyms: IMSS, ISSSTE, PEMEX).
- *Years of Schooling.* Average years of education for population aged 15 and above.

In our baseline specifications in Table 2, we include municipality-year fixed effects, but in Appendix Tables A.5-A.10, we include state-year effects and interactions of initial values of the following municipality characteristics with the Post dummy:

- *Altitude.* Altitude of municipality. Drawn from the *Sistema Nacional de Información Municipal (SNIM)* [National System of Municipal Information], produced by the *Instituto Nacional para el Federalismo y el Desarrollo Municipal (INAFED).*
- *Infant mortality.* The number of deaths of young children under the age of 1 per 1000 births. Source: SNIM.
- *Malnutrition.* Fraction of people who are unable to obtain a basic food basket, even if all the household's disposable income were used to purchase only the goods in the basic food basket. Reported by *Consejo Nacional de Evaluación de la Política de Desarrollo Social (CONEVAL).*[10]
- *Marginalization Index.* This index uses principal component analysis to obtain a normalized standard deviation score between -3 and 3 from the following indicators: the fraction of illiterate people of 15 years old or above; the fraction of people without completing primary education of 15 years old or above; the fraction of people in households without water access; the fraction of people in households without sewage facilities; the fraction of people in households with ground floor (without concrete or wooden floor); the fraction of people in households without electricity access; the fraction of households with some level of overcrowding; the share of the employed population earning less than twice the minimum wage; the share of people living in localities with less than 5,000 inhabitants. Reported by the *Consejo Nacional de Población (CONAPO).*[11]
- *Homicides.* Number of homicides, calculated from homicide data provided by INEGI.[12]
- *Labor Income per Capita.* Average yearly earned labor income, calculated from 10% sample of 2000 population census available at IPUMS.[13]

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[10] Downloaded from https://www.coneval.org.mx/rw/resource/Estados_y_Municipios1.xls.zip on Dec. 17, 2020.

[11] Downloaded from http://www.conapo.gob.mx/work/models/CONAPO/indices_margina/margina2005/AnexoB.xls on Dec. 17, 2020.

[12] Downloaded from http://www.inegi.org.mx/sistemas/olap/Proyectos/bd/continuas/mortalidad/DefuncionesHom.asp?s=est&c=28820&proy=mortgral_dh. on March 5, 2014.

[13] The original questionnaire asks the frequency (two weeks, month, year, etc) that the income refers to, but IPUMS normalizes to monthly income, which was multiplied by 12 to get annual income.

- *Municipality Tax Revenue per Capita.* Municipality-level tax collection available from the INEGI's System of Municipal Accounts (*Sistema de Cuentas Municipales*).[14]
- *Gini Index.* Gini Index for 2005. Source: CONEVAL.[15]

C Analysis of U.S. Exports

C.1 Test for Structural Break in U.S. Exports

As mentioned in Section IV.B of the main text, this section conducts a standard Quandt likelihood ratio test for a structural break in ULAB exports (Quandt, 1960; Andrews, 1993, 2003; Hansen, 2000). We estimate the following regression separately for many different possible values of the date (month-year) of the break, denoted by τ:

$$lnY_t = \alpha + \beta_{1\tau} D_t(\tau) \times Trend_t + \beta_{2\tau} D_t(\tau) + \beta_3 Trend_t + \varepsilon_t, \tag{A1}$$

where the dependent variable is the log number of ULAB exported from the U.S. to Mexico, $D_t(\tau)$ is an indicator variable equal to one for all months after τ and zero otherwise, and *Trend* is a monthly trend.[16] In order to have sufficient data to estimate pre- and post-trends, and motivated by Figure 2, we focus on the window between January 2007 and December 2010 as possible values of τ.[17] For each value of τ, we conduct an F test of the joint significance of $\beta_{1\tau}$ and $\beta_{2\tau}$, which capture the deviation of the time series from a linear trend at the break date τ, and compare it to the critical values provided by Andrews (1993, 2003). Figure A.5 plots the values of these F statistics and the 1% critical value (the horizontal dashed line). The F statistic reaches a maximum in July 2009, and is clearly above the critical value in May–Aug. 2009. In short, consistent with the clear visual evidence in Figure 2, there is strong evidence of a structural break in U.S. ULAB exports to Mexico following almost immediately after the tightening of the air quality standard in the U.S. There was an additional significant acceleration of ULAB exports in mid-2010.

C.2 Difference-in-Differences for U.S. Exports

A potential concern with the trend-break analysis in the previous subsection is that there might have been other shocks in 2008–9 that led to a general increase in exports from the U.S. to Mexico for related goods. To address this issue, we compare ULAB exports to exports for other 10-digit

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[14] Downloaded from https://www.inegi.org.mx/contenidos/programas/finanzas/datosabiertos/efipem_cdmx_csv.zip on Dec. 17, 2020.

[15] Downloaded from https://www.coneval.org.mx/rw/resource/Nacional.xls.zip on Dec. 17, 2020.

[16] We drop the values of exports in May and June 2008, which are outliers; the results are qualitatively similar when we retain these observations.

[17] The literature provides little guidance over the choice of the appropriate window. Our focus between 2007 and 2010 is primarily motivated by the pattern illustrated in Figure 2. Trimming 15% from the boundaries of the sample, as suggested by Andrews (1993, 2003), yields similar results.

U.S. tariff codes (often referred to as HS10 codes, for Harmonized System 10-digit) that map into the 3-digit NAICS sector in which battery recycling is typically classified, Primary Metal Manufacturing, 331. Concordances from the Census Bureau, as cleaned and organized by Pierce and Schott (2012), map each HS10 codes into a single NAICS 6-digit sector.[18] We keep the HS10 codes that map into a NAICS 6-digit sector contained in NAICS 331. We sum the three HS10 codes corresponding to used lead-acid batteries (8548100540, 8548100580, and 8548102500) into a separate category.

In our difference-in-difference analysis, we estimate an equation of the following form:

$$\ln Y_{imt} = \alpha + \sum_{\tau} \beta_{\tau}(ULAB_i \times \tau_{mt}) + \lambda_i + \widetilde{\tau}_{mt} + \epsilon_{imt} \tag{A2}$$

where i indexes product m and t index month and year, Y_{imt} is quantity exported, $ULAB_i$ is a 0/1 variable indicating used lead-acid batteries, λ_i is a product effect, τ_{mt} is an indicator for month-year or other time period, $\widetilde{\tau}_{mt}$ is also an indicator for time period (which may differ from τ_{mt}), and ϵ_{imt} is a mean-zero disturbance. The coefficients of interest are the β_{τ}, which arguably capture the effect of the environmental reform on exports. We focus on quantity exported, as in Appendix C.1, rather than value of exports, to avoid conflating quantities with prices, which in the case of ULABs declined steadily following the 2009 reform. Errors are clustered at the product (HS10) level.

Appendix Figure A.6 plots estimates β_{τ} from (A2) where both τ_{mt} and $\widetilde{\tau}_{mt}$ are defined as month-year effects. We see that there is no significant pre-trend before the ANPR in Dec. 2007 and that exports of ULABs clearly increased relative to other products in the same broad sector following the implementation of the reform. In the middle months of 2008, it appears that there was a rush to export ULABs and a dip thereafter (a pattern that can also be seen in Figure 2), perhaps because firms were uncertain when the new lead standard would be implemented. But the patterns before Dec. 2007 and after Jan. 2009 are clear.

To check robustness, Appendix Table A.2 reports regressions similar to (A2) but the $ULAB_i$ indicator is interacted either with a *Post* dummy, taking the value 1 for Jan. 2009 and later and 0 otherwise (Columns (1)–(2)), or a set of year effects (Columns (3)–(4)). The odd-numbered columns include separate year and month effects, and the even-numbered ones include a full set of year-month effects. The results are quite consistent with Appendix Figure A.6: exports of ULABs rose relative to other products in the same broad sector following the tightening of the U.S. lead standard.

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[18] We use the updated concordance available at Schott's webpage: url https://faculty.som.yale.edu/peterschott/international-trade-data/.

D Population Characteristics near Binding vs. Non-Binding Plants

In the Conclusion, we mention that people living near "binding" plants in the U.S. tend to be disadvantaged relative to those living near "non-binding" plants. Appendix Table A.15 uses tract-level estimates from the 2010 American Community Survey (ACS) to characterize this difference. We use the ACS 5-year estimates. As in Appendix Figure A.3, plants are considered binding if the pre-2008 average lead concentrations over all nearby ($\leq$ 2 mi.) monitors measuring lead (for which a given plant is the nearest lead emitter) exceeds the new standard. Other lead-emitting plants are considered non-binding. We calculate the distance from census tracts to lead-emitting plants using the longitude and latitude reported for tracts by the ACS. No tract is near both a binding and a non-binding plant. We see that people living near binding plants in the U.S are much more likely to be Hispanic and to have less than a high school degree. They also have lower median household income on average.

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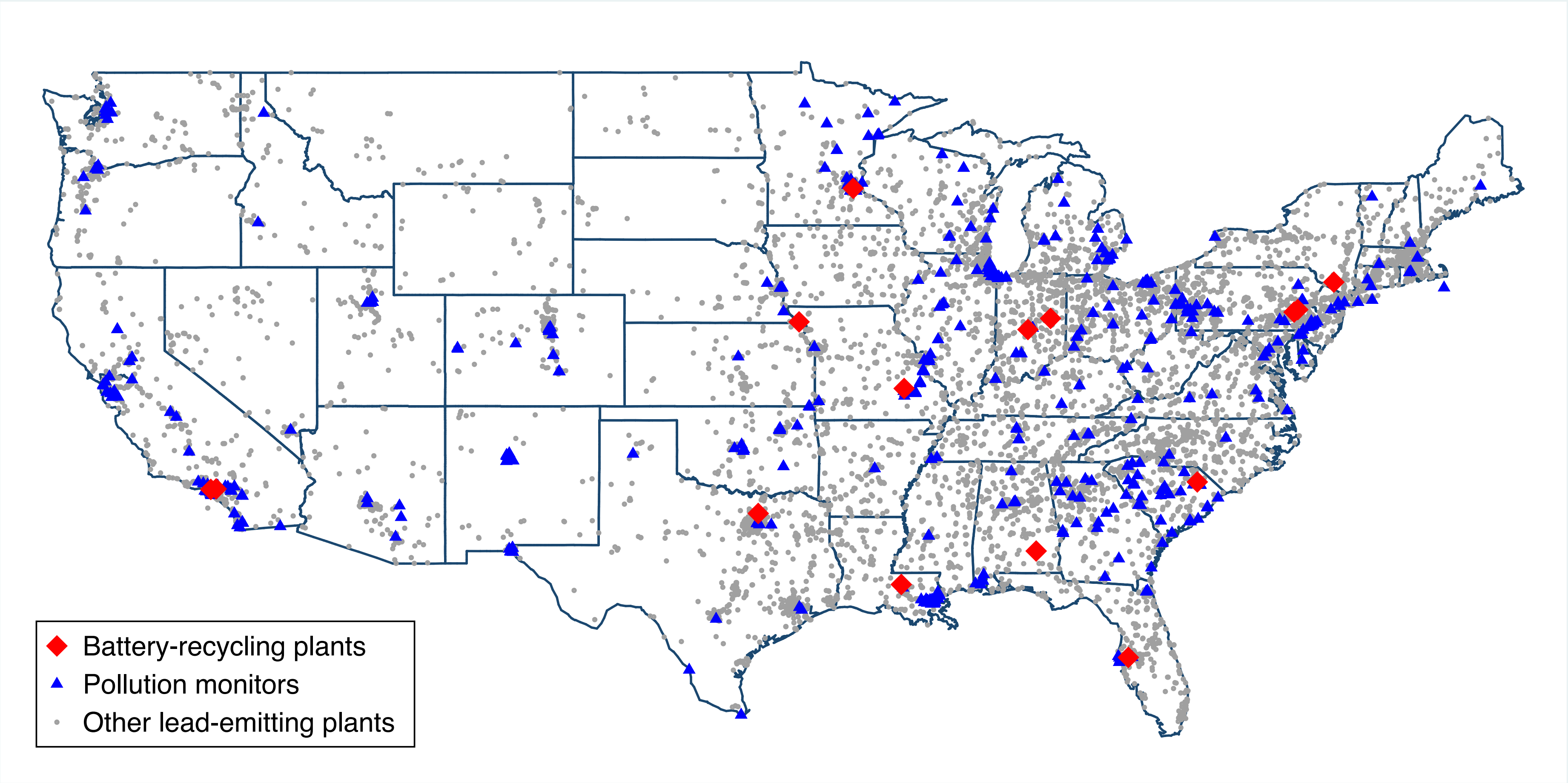
Figure A.1. Locations of Plants and Monitors in the U.S.

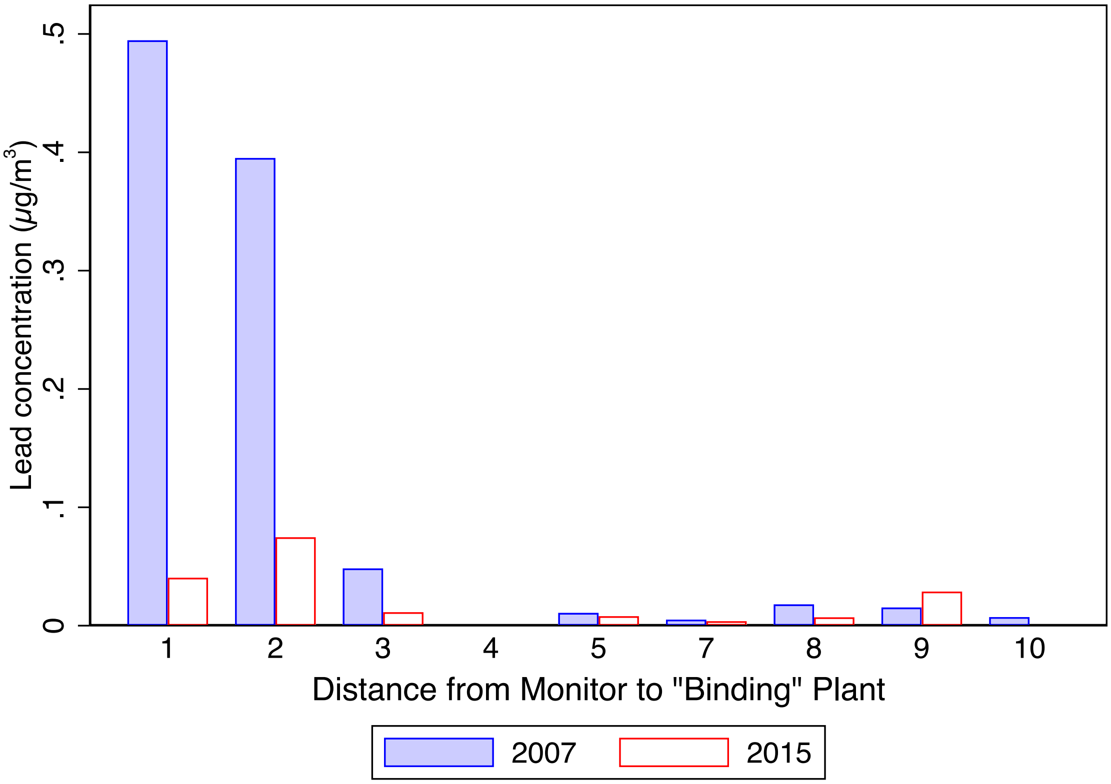


Notes: This map shows the locations of battery recycling plants, other lead-emitting plants, and pollution monitors maintained by the U.S. Environmental Protection Agency that monitor lead active in our study period.

Figure A.2. Locations of Plants in Mexico

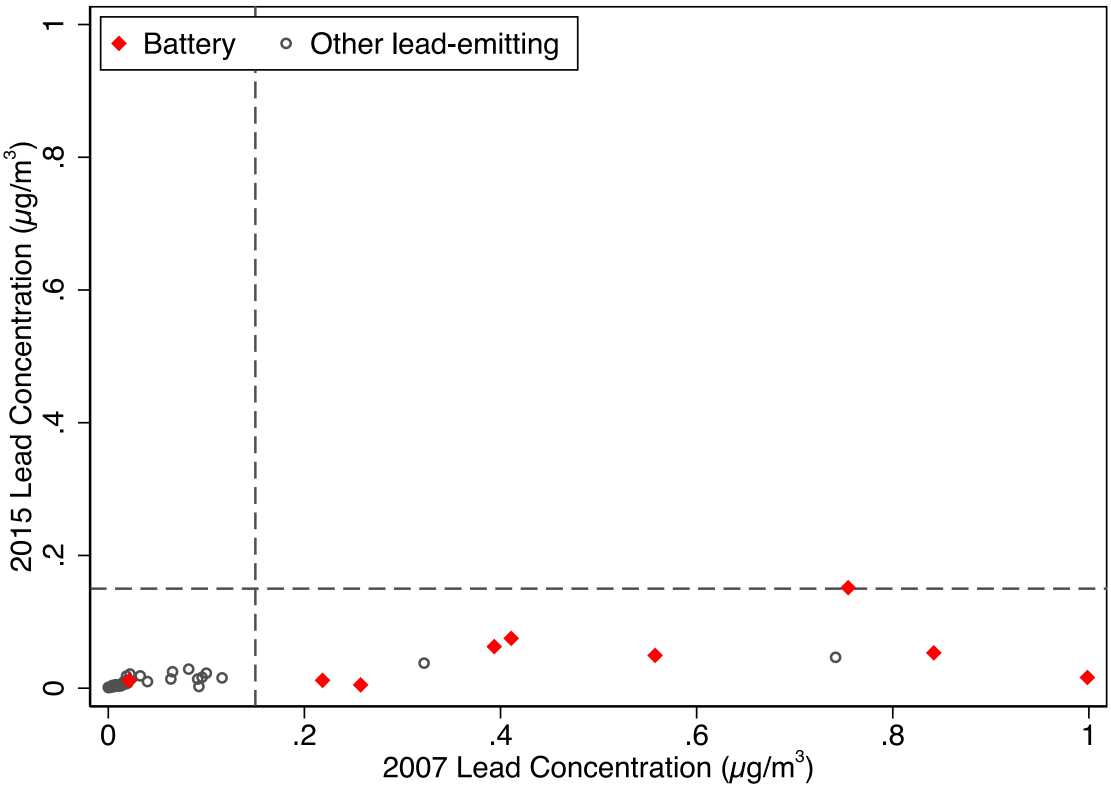
Notes: This map shows the locations of 26 Mexican battery-recycling plants constructed from CEC (2013) and the Mexican *Registro de Emisiones y Transferencia de Contaminantes* (RETC). Several plants are located close to one another and are difficult to distinguish visually.

Figure A.3. Lead Concentration vs. Distance from U.S. Lead-Emitting Plants



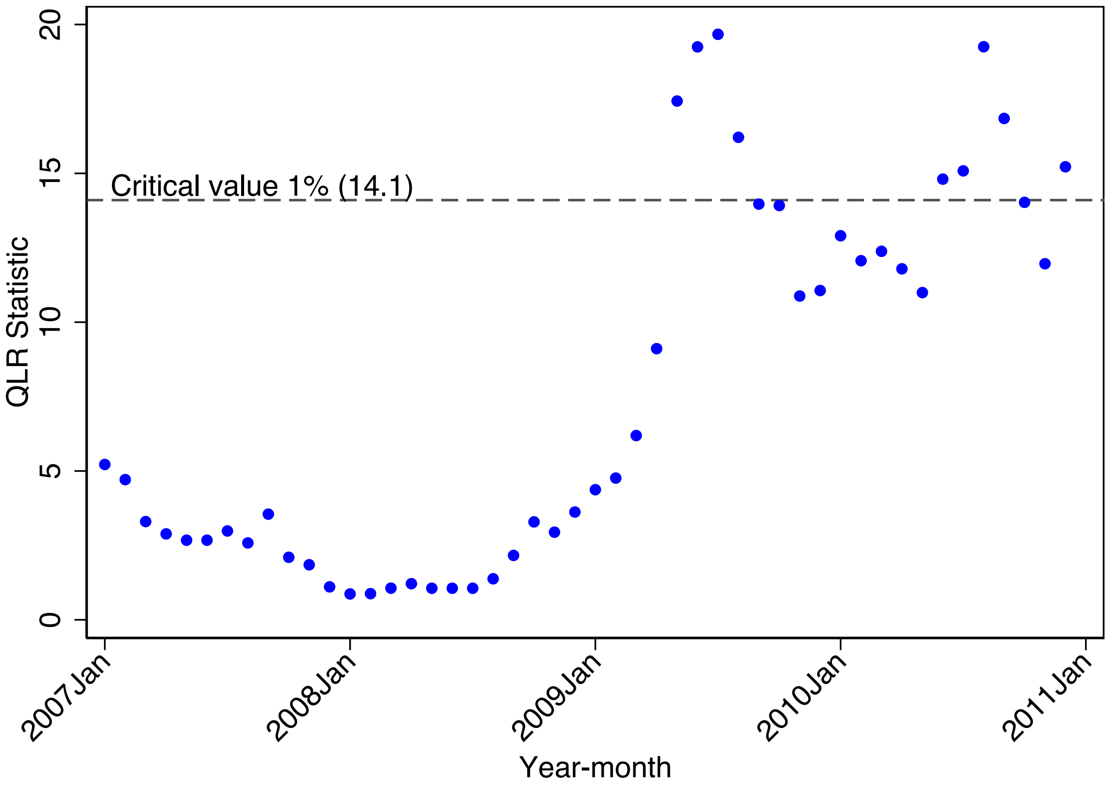
Notes: A plant is considered to be "binding" if average lead concentration at nearby monitors ($\leq$ 2 mi.) is above the new standard (0.15 $\mu g/m^3$) prior to 2009 reform. The figure shows average ambient lead concentrations at monitors by 1-mile distance bin from such plants.

Figure A.4. Lead Concentrations Near U.S. Lead-Emitting Plants, 2007 and 2015



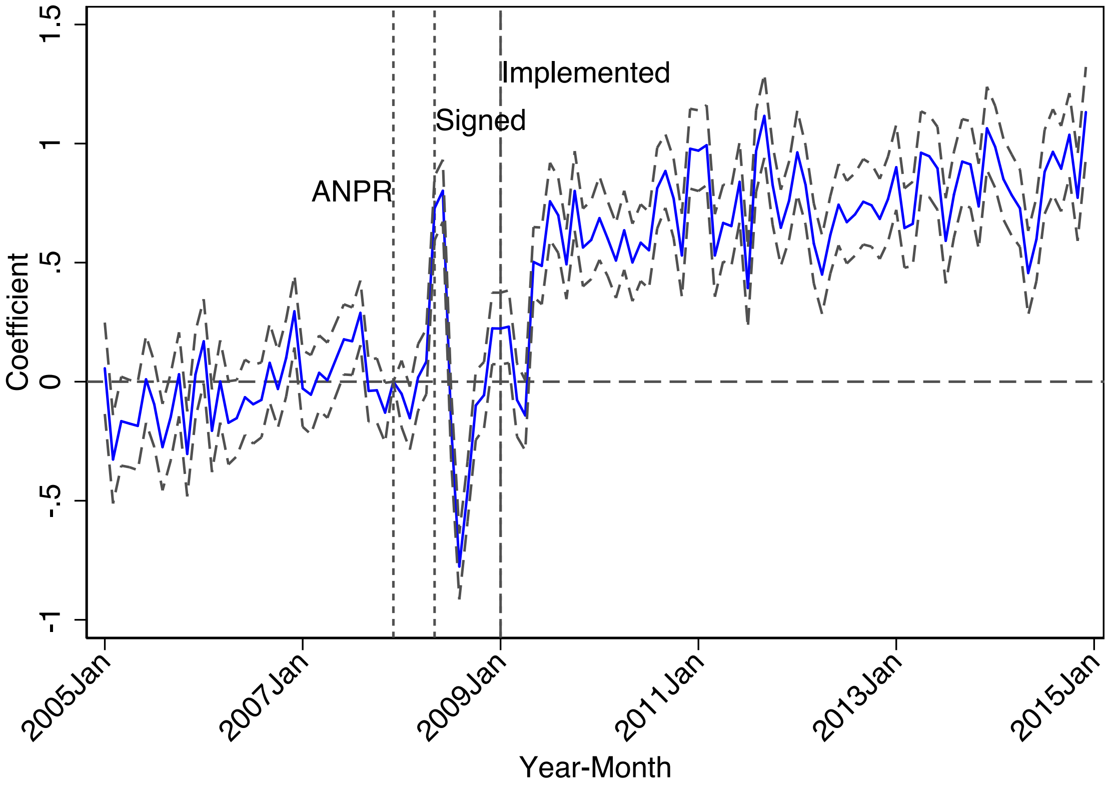
Notes: The figure plots average lead concentrations at the plant level, where averages are calculated over all nearby ($\leq$ 2 mi.) monitors measuring lead for which a given plant is the nearest lead emitter. The dashed lines indicate the revised air-quality standard (NAAQS) for lead (0.15 $\mu g/m^3$). Two battery plants have average 2007 concentrations of approximately 0.02.

Figure A.5. Testing for a Trend Break in U.S. ULAB Exports



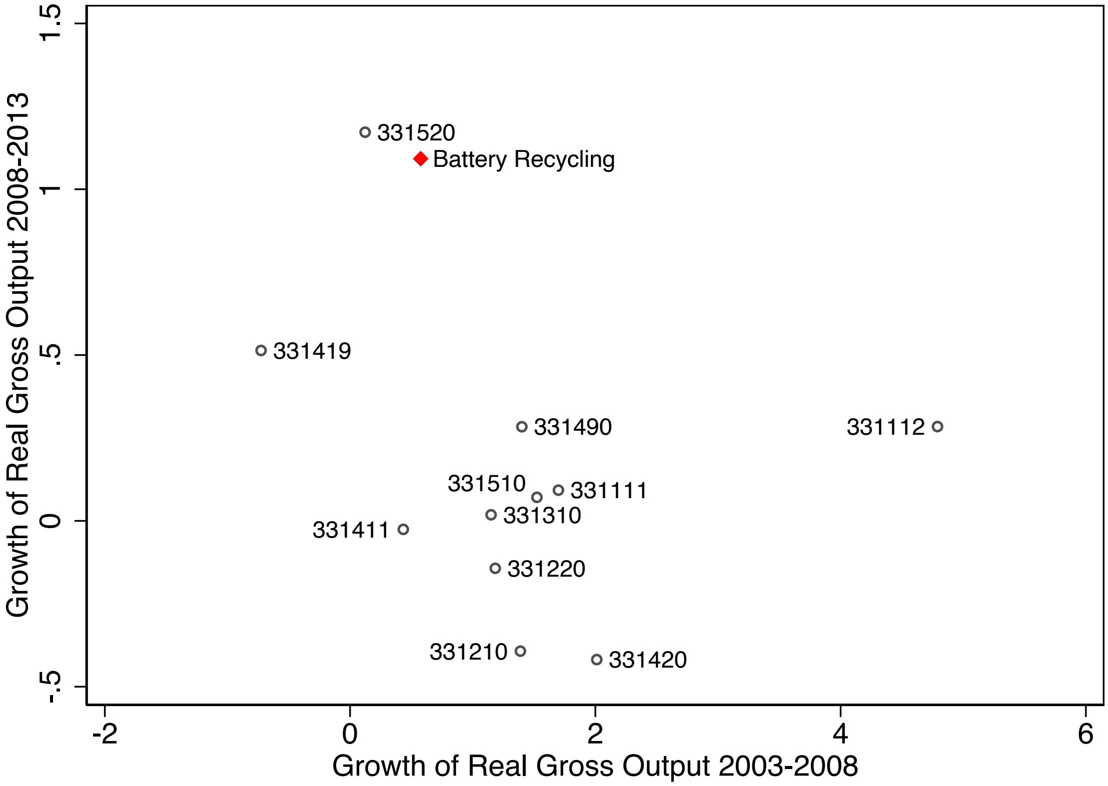
Notes: The figure above presents the Quandt Likelihood Ratio (QLR) statistics for a potential trend break in months between 2007 and 2010 using the sample of 2004–2014. The asymptotic critical value at the 1 percent significance level is provided by Andrews (1993, 2003).

Figure A.6. Difference in Differences for U.S. ULAB Exports



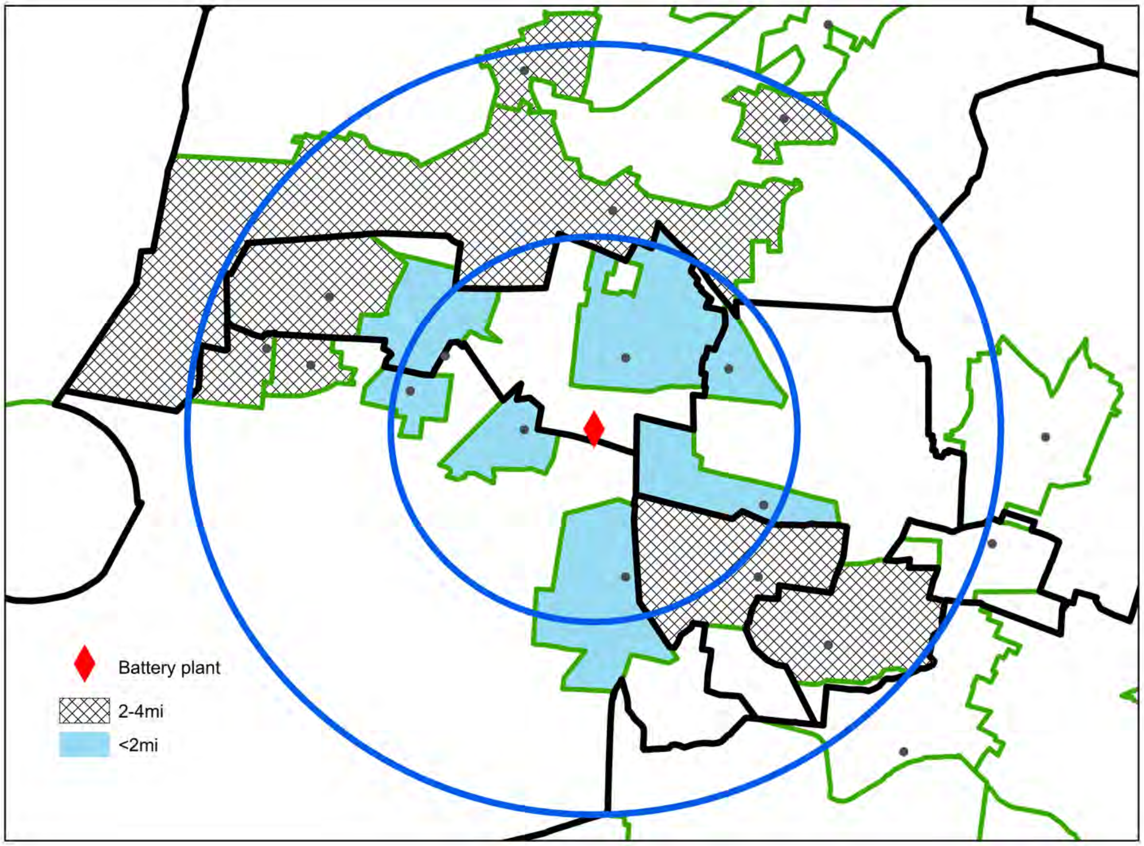
Notes: Figure reports estimates of β_τ from equation (A2). Sample includes exports for HS10 products that map to NAICS 331 (Primary Metal Manufacturing) plus battery recycling (which sums HS10 categories 8548100540, 8548100580, and 8548102500). The gray dotted lines indicate 95% confidence intervals. Errors are clustered at the product (HS10) level.

Figure A.7. Output in Battery Recycling vs. Similar Industries in Mexico



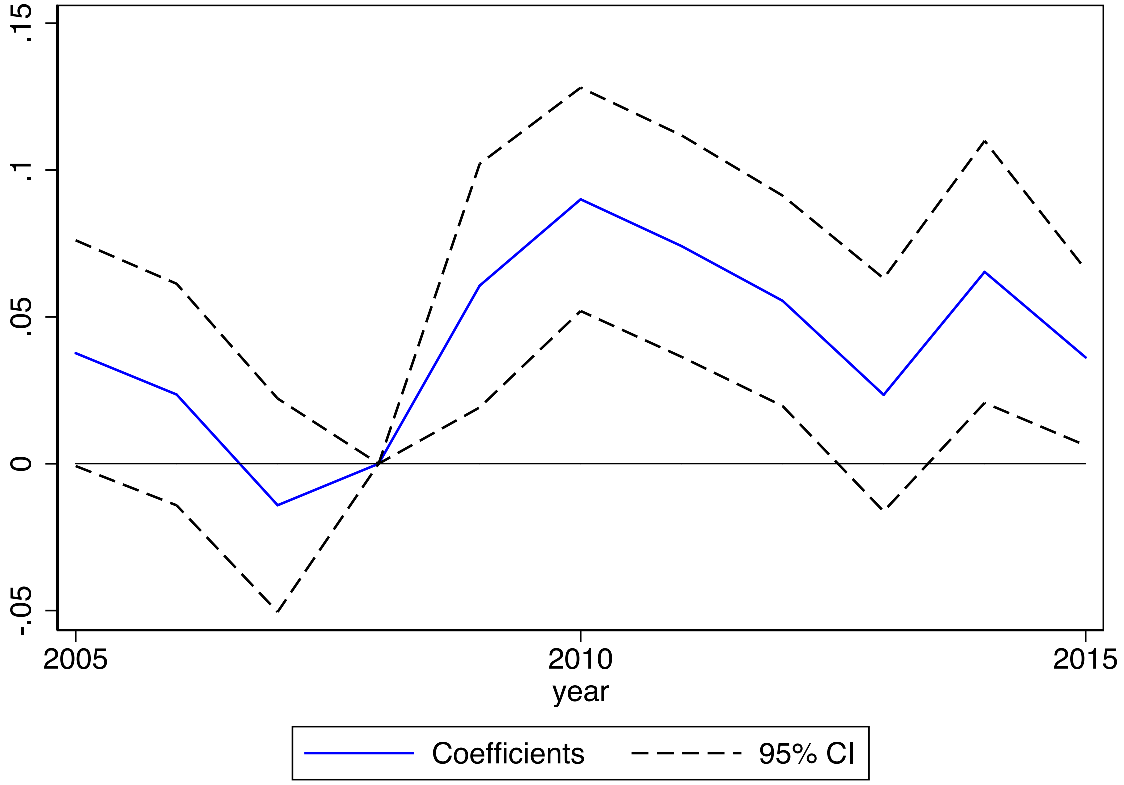
Notes: Output by 6-digit industry is taken from the 2004, 2009, and 2014 Economic Censuses (data for 2003, 2008, and 2013), for North American Industry Classification System (NAICS) sector 331 of (Primary Metal Manufacturing). Growth of output is defined as $((y_t - y_{t-1})/y_{t-1})$. The detailed 6-digit industries are: 331111 – Iron and steel mills; 331112 – Primary roughs and ferroalloy manufacturing; 331210 – Iron and steel pipe and tube manufacturing; 331220 – Other iron and steel product manufacturing; 331310 – Aluminum production; 331411 – Copper smelting and refining; 331412 – Precious metals smelting and refining; 331419 – Other nonferrous metals smelting and refining; 331420 – Secondary lamination of copper; 331490 – Secondary lamination of other nonferrous metals; 331510 – Iron and steel parts molded by casting; 331520 – Nonferrous metallic parts molded by casting.

Figure A.8. Illustration of Distance Bins



Notes: The map illustrates distance bins near a battery-recycling plant in the municipality of Tezoyuca, Estado de México. The concentric circles are at 2 miles and 4 miles away from the plant. Localities are classified as "near" if the latitude/longitude of a locality (as assigned by INEGI, and indicated by a dot) falls within 2-mi. circle. These localities are compared to localities with latitude/longitude falling between 2-mi/ and 4-mi. circles. Shapefiles are not available from INEGI for localities with fewer than 100 inhabitants, and we omit them from the figure (although not from the regression analysis). Black lines indicate municipality boundaries, and green lines locality boundaries.

Figure A.9. Effect on Low Birthweight, Year by Year



Notes: Coefficient estimates from specification similar to Table 2, Panel A.2, Column (4), but interacting "Near Battery" indicator with year dummies. Dependent variable is the incidence of low birthweight. Omitted period is 2008. Dashed lines show the 95 percent confidence intervals.

Table A.1. Summary Statistics, U.S. Pollution Monitors

	Sample near any lead-emitter (1)	Sample near battery plant (2)
Lead concentration ($\mu g/m^3$)	0.088	0.220
	(0.241)	(0.369)
Distance to emitter (mile)	0.658	0.387
	(0.510)	(0.273)
Share 0–1 mile	0.730	0.946
	(0.444)	(0.225)
Share 1–2 mile	0.270	0.054
	(0.444)	(0.225)
N (monitors)	142	22
N (observations)	16858	3133

Notes: Samples are monitors within 2 miles of any lead-emitting plant (Column (1)) and of any battery-recycling plant (Column (2)). Standard deviations are in parentheses. Source: U.S. Environmental Protection Agency API.

Table A.2. Difference-in-Differences Analysis, U.S. Exports

	Outcome: ln(quantity exported)			
	(1)	(2)	(3)	(4)
ULAB X Post	0.738***	0.737***		
	(0.0466)	(0.0467)		
ULAB X 2005			-0.134**	-0.136**
			(0.0624)	(0.0625)
ULAB X 2006			-0.0182	-0.0196
			(0.0520)	(0.0519)
ULAB X 2007			0.0256	0.0289
			(0.0374)	(0.0373)
ULAB X 2009			0.423***	0.421***
			(0.0385)	(0.0386)
ULAB X 2010			0.666***	0.664***
			(0.0488)	(0.0489)
ULAB X 2011			0.775***	0.774***
			(0.0514)	(0.0515)
ULAB X 2012			0.703***	0.702***
			(0.0564)	(0.0565)
ULAB X 2013			0.831***	0.829***
			(0.0623)	(0.0624)
ULAB X 2014			0.836***	0.834***
			(0.0643)	(0.0644)
Observations	52404	52404	52404	52404
Product Effects	Y	Y	Y	Y
Year Effects	Y	N	Y	N
Month Effects	Y	N	Y	N
Year-Month Effects	N	Y	N	Y

Notes: Table reports estimates of equation (A2) in Appendix C.2. Data are at the level of HS10 category-year. Included are HS10 categories that map to NAICS Sector 331 (Primary Metal Manufacturing) plus an aggregate used lead-acid battery category, for which *ULAB* is an indicator. Outcome is log quantity exported, where units of measurement do not change within HS10 category. Product effects are indicators for HS10 categories. Robust standard errors, clustered at the product (HS10) level, are in parentheses. *10% level, **5% level, ***1% level.

Table A.3. Summary Statistics, Mexico Birth and Mother Characteristics, Pre-Reform

	Hospital-discharge data (2005–2008)		Birth-certificate data (2008 only)					
	Ministry of Health		Ministry of Health		Other public		Private	
	(1) ≤ 2mi	(2) 2–4mi	(3) ≤ 2mi	(4) 2–4mi	(5) ≤ 2mi	(6) 2–4mi	(7) ≤ 2mi	(8) 2–4mi
Birthweight (grams)	3006.6	3099.9	3011.4	3084.2	3078.8	3109.2	3095.1	3066.2
	(3.946)	(1.762)	(7.042)	(3.530)	(5.756)	(3.664)	(5.142)	(4.393)
Low birthweight indicator	0.128	0.100	0.124	0.102	0.100	0.094	0.071	0.094
	(0.003)	(0.001)	(0.005)	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)
Gestation period (weeks)	38.665	38.678	38.692	38.742	38.698	38.728	38.640	38.306
	(0.015)	(0.006)	(0.024)	(0.012)	(0.021)	(0.013)	(0.016)	(0.014)
Premature birth indicator	0.094	0.084	0.080	0.077	0.092	0.084	0.052	0.088
	(0.002)	(0.001)	(0.004)	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)
Mother's age	24.059	24.264	23.801	23.961	26.231	26.449	25.869	27.511
	(0.047)	(0.021)	(0.089)	(0.044)	(0.069)	(0.042)	(0.071)	(0.057)
Live birth	0.914	0.883						
	(0.002)	(0.001)						
Married			0.242	0.468	0.612	0.818	0.494	0.732
			(0.006)	(0.004)	(0.006)	(0.003)	(0.006)	(0.004)
Single			0.177	0.145	0.092	0.072	0.089	0.067
			(0.005)	(0.003)	(0.003)	(0.002)	(0.003)	(0.002)
Civil union			0.579	0.382	0.293	0.105	0.414	0.198
			(0.007)	(0.003)	(0.005)	(0.002)	(0.006)	(0.004)
1st live birth			0.399	0.409	0.360	0.353	0.431	0.423
			(0.007)	(0.004)	(0.006)	(0.004)	(0.006)	(0.005)
2nd live birth			0.291	0.267	0.364	0.328	0.338	0.329
			(0.006)	(0.003)	(0.006)	(0.003)	(0.005)	(0.004)
>2 live birth			0.310	0.324	0.276	0.319	0.232	0.249
			(0.007)	(0.003)	(0.005)	(0.003)	(0.005)	(0.004)
Previous birth stillborn			0.059	0.054	0.061	0.059	0.058	0.071
			(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)
Received prenatal care			0.951	0.949	0.988	0.984	0.983	0.994
			(0.003)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
0-6 Yrs Educ			0.230	0.389	0.098	0.235	0.129	0.127
			(0.006)	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)
7-9 yrs educ			0.473	0.409	0.377	0.397	0.301	0.252
			(0.007)	(0.004)	(0.006)	(0.004)	(0.005)	(0.004)
10+ yrs educ			0.297	0.202	0.525	0.368	0.571	0.620
			(0.007)	(0.003)	(0.006)	(0.004)	(0.006)	(0.005)
N (hospitals)	87	125	89	108	76	95	80	166
N (observations)	18,518	95,323	4,892	19,439	7,374	18,451	7,507	11,344

Notes: Standard errors are in parentheses. Samples: Columns (1)–(2) include all births (including infant deaths) in hospital-discharge records from Ministry of Health (MH) hospitals 2005–2008 with mother's residential locality ≤ 2 miles or 2–4 miles from battery-recycling plant. (Means for variables beside Live birth are conditional on live birth.) Columns (3)–(8) include live births from birth certificates for 2008, for MH, other public, and private hospitals, with mother's residential locality ≤ 2 or 2–4 miles from battery-recycling plant. Birthweight and gestation period have been winsorized at the 1st and 99th percentiles. Low birthweight indicator equals 1 if birthweight is below 2.5 kg, 0 otherwise. Premature birth indicator equals 1 if gestation period is fewer than 37 weeks, 0 otherwise. Columns (1)–(2) means (except for the live birth variable itself) are conditional on live birth. N (hospitals) indicates number of hospitals that appear in each sample; the sets of hospitals overlap across distance bins. Characteristics omitted from the table include divorced/widowed/other and > 2 previous live births, which sum to 1 with other indicators of marital status and parity, respectively.

Table A.4. Summary Statistics, Locality and Municipality Characteristics

	Min. of Health hospital-discharge data	Birth-certificate data		
		Ministry of Health	Other public	Private
	(1)	(2)	(3)	(4)
Panel A: Locality characteristics				
Share hhs with water	0.918	0.910	0.906	0.907
	(0.000)	(0.001)	(0.000)	(0.001)
Share hhs with electricity	0.950	0.950	0.944	0.942
	(0.000)	(0.000)	(0.000)	(0.000)
Share hhs with sewerage	0.942	0.938	0.937	0.929
	(0.000)	(0.000)	(0.000)	(0.000)
Share pop $\leq$ 5 yrs	0.135	0.136	0.143	0.142
	(0.000)	(0.000)	(0.000)	(0.000)
ln(population)	12.962	12.579	12.541	12.039
	(0.005)	(0.013)	(0.011)	(0.015)
Share of pop with soc sec	0.537	0.527	0.538	0.501
	(0.000)	(0.001)	(0.001)	(0.001)
Avg yrs educ	8.895	8.821	8.974	9.164
	(0.003)	(0.006)	(0.005)	(0.008)
Panel B: Municipality characteristics				
Infant mortality	11.085	11.283	10.663	10.621
	(0.009)	(0.020)	(0.016)	(0.025)
Malnutrition	8.482	8.831	8.434	9.159
	(0.012)	(0.028)	(0.018)	(0.039)
Homicides per 100K pop	6.396	6.693	7.434	8.396
	(0.012)	(0.029)	(0.030)	(0.038)
Marginalization index	-1.527	-1.513	-1.580	-1.572
	(0.001)	(0.002)	(0.001)	(0.002)
Labor income per capita (000s 2000 pesos)	18.221	17.973	18.324	17.620
	(0.008)	(0.019)	(0.015)	(0.025)
Gini coefficient (income)	0.438	0.434	0.426	0.424
	(0.000)	(0.000)	(0.000)	(0.000)
Tax revenue per capita	207.9	204.693	223.908	215.808
	(0.199)	(0.455)	(0.435)	(0.657)
Altitude	1891.3	1919.425	2008.935	2061.124
	(1.199)	(2.545)	(1.742)	(2.390)
N (hospitals)	151	140	121	203
N (observations)	113,841	24,331	25,825	18,851

Notes: Standard errors of means in parentheses. Data sources and variable definitions are in Appendix B.6. Locality and municipality characteristics are assigned to birth records based on mother's residence. Samples pool distance-bin-specific samples from Appendix Table A.3.

Table A.5. Low Birthweight Indicator, Hospital-Discharge Data

	Outcome: 1(Birthweight < 2.5 kg)				
	(1)	(2)	(3)	(4)	(5)
Near*Post	0.031***	0.022***	0.043***	0.049***	0.048***
	(0.0086)	(0.0081)	(0.011)	(0.012)	(0.011)
Mother's Age	-0.0085***	-0.0085***	-0.0085***	-0.0072***	-0.0072***
	(0.00073)	(0.00073)	(0.00073)	(0.00059)	(0.00062)
Mother's Age Squared	0.00017***	0.00017***	0.00017***	0.00014***	0.00014***
	(0.000013)	(0.000013)	(0.000013)	(0.000012)	(0.000013)
1(1≤ Other ≤5)*Post	-0.011		-0.043	-0.043	-0.056*
	(0.026)		(0.033)	(0.032)	(0.031)
1(6≤ Other ≤10)*Post	0.0093		-0.11*	-0.14***	-0.14**
	(0.035)		(0.057)	(0.054)	(0.056)
1(Other ≥11)*Post	-0.059		-0.16**	-0.076	-0.051
	(0.038)		(0.066)	(0.060)	(0.075)
Share HHs w/ Water*Post	0.042		0.023	0.046	0.017
	(0.077)		(0.087)	(0.085)	(0.084)
Share HHs w/ Elect.*Post	0.20		-0.012	-0.21	-0.070
	(0.48)		(0.69)	(0.70)	(0.65)
Share HHs w/ Sewer*Post	-0.015		-0.091	-0.12	-0.079
	(0.14)		(0.14)	(0.14)	(0.13)
Share Pop. Age 0-4*Post	0.014		1.28**	1.43**	1.64***
	(0.51)		(0.60)	(0.60)	(0.55)
Log Pop.*Post	-0.012***		-0.019***	-0.021***	-0.021***
	(0.0035)		(0.0065)	(0.0067)	(0.0064)
Share Pop. w/ Soc. Sec.*Post	-0.22***		-0.17	-0.14	-0.073
	(0.075)		(0.14)	(0.13)	(0.14)
Avg. Yrs. Schooling*Post	0.026***		0.043**	0.047***	0.048***
	(0.0068)		(0.018)	(0.018)	(0.018)
Observations	319165	319165	319165	319165	319165
Region-Year Effects	State-year	Mun-year	Mun-year	Mun-year	Mun-year
Locality Effects	Y	Y	Y	Y	Y
Municipality Chars.*Post	Y	N	N	N	N
Hospital Effects	N	N	N	Y	N
Hospital-Year Effects	N	N	N	N	Y
Pre-Reform Mean (Near=1)	0.128	0.128	0.128	0.128	0.128

Notes: Columns (2)-(5) report same regressions as Table 2, Panel A.1, with more complete reporting of coefficient estimates; Column (1) reports an alternative specification with municipality characteristics (listed in Appendix B.6) interacted with a Post (≥2009) dummy in place of municipality-year effects. See notes to Table 2 for details. Robust standard errors, clustered at the locality level, are in parentheses. *10% level, **5% level, ***1% level.

Table A.6. Birthweight, Hospital-Discharge Data

	Outcome: Birthweight (grams)				
	(1)	(2)	(3)	(4)	(5)
Near*Post	-23.5**	-35.0***	-32.3**	-40.4**	-38.5**
	(11.3)	(10.2)	(16.0)	(16.2)	(16.3)
Mother's Age	24.9***	25.0***	25.0***	22.7***	22.7***
	(0.73)	(0.73)	(0.73)	(0.95)	(0.98)
Mother's Age Squared	-0.39***	-0.39***	-0.39***	-0.34***	-0.34***
	(0.014)	(0.014)	(0.014)	(0.020)	(0.020)
1(1≤ Other ≤5)*Post	-63.9		-16.8	-18.2	-4.79
	(39.7)		(53.5)	(54.4)	(52.9)
1(6≤ Other ≤10)*Post	-84.9*		98.4	136.8*	117.5
	(49.9)		(79.5)	(81.4)	(84.6)
1(Other ≥11)*Post	21.6		52.9	-111.1	-92.7
	(56.4)		(206.0)	(180.8)	(185.4)
Share HHs w/ Water*Post	-155.2		-148.0	-194.1*	-139.3
	(103.7)		(121.1)	(112.3)	(110.1)
Share HHs w/ Elect.*Post	458.1		669.5	909.9	660.7
	(693.0)		(1031.8)	(1072.2)	(1011.3)
Share HHs w/ Sewer*Post	90.2		40.8	94.4	29.9
	(157.8)		(180.6)	(190.8)	(192.4)
Share Pop. Age 0-4*Post	592.8		-717.3	-884.2	-1081.3
	(744.5)		(936.9)	(953.0)	(896.7)
Log Pop.*Post	12.4*		22.6**	26.6**	24.5**
	(6.68)		(10.8)	(10.9)	(11.2)
Share Pop. w/ Soc. Sec.*Post	207.7*		67.8	41.4	-19.6
	(112.9)		(225.9)	(225.5)	(236.3)
Avg. Yrs. Schooling*Post	-25.0**		-38.7	-42.6*	-40.2
	(10.1)		(26.0)	(25.7)	(25.9)
Observations	319165	319165	319165	319165	319165
Region-Year Effects	State-year	Mun-year	Mun-year	Mun-year	Mun-year
Locality Effects	Y	Y	Y	Y	Y
Municipality Chars.*Post	Y	N	N	N	N
Hospital Effects	N	N	N	Y	N
Hospital-Year Effects	N	N	N	N	Y
Pre-Reform Mean (Near=1)	3006.6	3006.6	3006.6	3006.6	3006.6

Notes: Columns (2)-(5) report same regressions as Table 2, Panel A.2, with more complete reporting of coefficient estimates; Column (1) reports an alternative specification with municipality characteristics (listed in Appendix B.6) interacted with a Post (≥2009) dummy in place of municipality-year effects. See notes to Table 2 for details. Robust standard errors, clustered at the locality level, are in parentheses. *10% level, **5% level, ***1% level.

Table A.7. Very Low Birthweight Indicator, Hospital-Discharge Data

	Outcome: 1(Birthweight<1.5 kg)				
	(1)	(2)	(3)	(4)	(5)
Near*Post	0.00079	0.0047	0.0056	0.0073*	0.0069*
	(0.0047)	(0.0034)	(0.0042)	(0.0039)	(0.0037)
Mother's Age	-0.0016***	-0.0016***	-0.0016***	-0.0013***	-0.0013***
	(0.00014)	(0.00014)	(0.00014)	(0.00017)	(0.00016)
Mother's Age Squared	0.000037***	0.000037***	0.000037***	0.000030***	0.000029***
	(0.0000032)	(0.0000032)	(0.0000032)	(0.0000037)	(0.0000037)
1(1≤ Other ≤5)*Post	0.000069		-0.0030	-0.0027	-0.0031
	(0.010)		(0.013)	(0.013)	(0.013)
1(6≤ Other ≤10)*Post	0.0019		-0.013	-0.018	-0.012
	(0.012)		(0.013)	(0.013)	(0.014)
1(Other ≥11)*Post	-0.0074		0.00038	0.021	0.028
	(0.013)		(0.013)	(0.015)	(0.020)
Share HHs w/ Water*Post	0.000050		-0.0097	-0.0079	-0.018
	(0.023)		(0.025)	(0.024)	(0.024)
Share HHs w/ Elect.*Post	-0.032		-0.16	-0.18	-0.10
	(0.10)		(0.13)	(0.12)	(0.12)
Share HHs w/ Sewer*Post	0.011		0.0022	-0.0055	-0.00016
	(0.031)		(0.034)	(0.034)	(0.035)
Share Pop. Age 0-4*Post	-0.079		0.051	0.071	0.086
	(0.11)		(0.12)	(0.12)	(0.13)
Log Pop.*Post	-0.0028*		-0.0028	-0.0031	-0.0024
	(0.0015)		(0.0022)	(0.0021)	(0.0022)
Share Pop. w/ Soc. Sec.*Post	-0.021		-0.027	-0.025	-0.026
	(0.031)		(0.053)	(0.053)	(0.055)
Avg. Yrs. Schooling*Post	0.0030		0.0053	0.0062	0.0059
	(0.0032)		(0.0051)	(0.0051)	(0.0052)
Observations	319165	319165	319165	319165	319165
Region-Year Effects	State-year	Mun-year	Mun-year	Mun-year	Mun-year
Locality Effects	Y	Y	Y	Y	Y
Municipality Chars.*Post	Y	N	N	N	N
Hospital Effects	N	N	N	Y	N
Hospital-Year Effects	N	N	N	N	Y
Pre-Reform Mean (Near=1)	0.017	0.017	0.017	0.017	0.017

Notes: Columns (2)-(5) report regressions similar to Table 2, Panel A; Column (1) reports an alternative specification with municipality characteristics (listed in Appendix B.6) interacted with a Post (≥2009) dummy in place of municipality-year effects. See notes to Table 2 for details. Robust standard errors, clustered at the locality level, are in parentheses. *10% level, **5% level, ***1% level.

Table A.8. Gestation Length, Hospital-Discharge Data

	Outcome: Gestation Length (weeks)				
	(1)	(2)	(3)	(4)	(5)
Near*Post	0.00090	-0.012	0.019	-0.013	-0.019
	(0.062)	(0.050)	(0.078)	(0.075)	(0.077)
Mother's Age	0.047***	0.047***	0.047***	0.035***	0.035***
	(0.0027)	(0.0027)	(0.0027)	(0.0046)	(0.0047)
Mother's Age Squared	-0.0011***	-0.0011***	-0.0011***	-0.00088***	-0.00087***
	(0.000056)	(0.000056)	(0.000056)	(0.00010)	(0.00011)
1(1≤ Other ≤5)*Post	0.086		0.18	0.19	0.22
	(0.15)		(0.18)	(0.18)	(0.18)
1(6≤ Other ≤10)*Post	0.0079		0.63	0.72*	0.73*
	(0.22)		(0.39)	(0.40)	(0.39)
1(Other ≥11)*Post	0.15		-0.18	-0.61	-0.47
	(0.20)		(0.86)	(0.89)	(0.85)
Share HHs w/ Water*Post	-0.21		-0.32	-0.45	-0.29
	(0.33)		(0.34)	(0.32)	(0.33)
Share HHs w/ Elect.*Post	-2.64		0.062	0.59	-0.97
	(2.87)		(4.57)	(4.50)	(4.24)
Share HHs w/ Sewer*Post	-0.57		-0.49	-0.32	-0.35
	(0.77)		(0.80)	(0.80)	(0.79)
Share Pop. Age 0-4*Post	-1.09		-3.82	-3.66	-4.84
	(2.91)		(3.68)	(3.55)	(3.46)
Log Pop.*Post	0.063**		0.12***	0.13***	0.12***
	(0.027)		(0.041)	(0.041)	(0.042)
Share Pop. w/ Soc. Sec.*Post	0.12		0.20	0.19	0.057
	(0.52)		(0.77)	(0.78)	(0.78)
Avg. Yrs. Schooling*Post	-0.087*		-0.23*	-0.24**	-0.24**
	(0.044)		(0.12)	(0.12)	(0.12)
Observations	319165	319165	319165	319165	319165
Region-Year Effects	State-year	Mun-year	Mun-year	Mun-year	Mun-year
Locality Effects	Y	Y	Y	Y	Y
Municipality Chars.*Post	Y	N	N	N	N
Hospital Effects	N	N	N	Y	N
Hospital-Year Effects	N	N	N	N	Y
Pre-Reform Mean (Near=1)	38.665	38.665	38.665	38.665	38.665

Notes: Columns (2)-(5) report regressions similar to Table 2, Panel A; Column (1) reports an alternative specification with municipality characteristics (listed in Appendix B.6) interacted with a Post (≥2009) dummy in place of municipality-year effects. See notes to Table 2 for details. Robust standard errors, clustered at the locality level, are in parentheses. *10% level, **5% level, ***1% level.

Table A.9. Premature Birth Indicator, Hospital-Discharge Data

	Outcome: 1(gestation<37 weeks)				
	(1)	(2)	(3)	(4)	(5)
Near*Post	0.0091	0.015**	0.0087	0.016	0.016
	(0.0087)	(0.0069)	(0.011)	(0.011)	(0.011)
Mother's Age	-0.0067***	-0.0067***	-0.0067***	-0.0052***	-0.0052***
	(0.00059)	(0.00059)	(0.00059)	(0.0011)	(0.0011)
Mother's Age Squared	0.00015***	0.00015***	0.00015***	0.00012***	0.00012***
	(0.000013)	(0.000013)	(0.000013)	(0.000022)	(0.000023)
1(1≤ Other ≤5)*Post	-0.0055		-0.021	-0.022	-0.030
	(0.024)		(0.026)	(0.027)	(0.028)
1(6≤ Other ≤10)*Post	-0.0082		-0.11*	-0.13**	-0.13**
	(0.032)		(0.058)	(0.057)	(0.061)
1(Other ≥11)*Post	-0.030		0.15	0.21	0.21
	(0.033)		(0.22)	(0.22)	(0.20)
Share HHs w/ Water*Post	0.056		0.075	0.095*	0.059
	(0.047)		(0.048)	(0.051)	(0.052)
Share HHs w/ Elect.*Post	-0.031		0.039	-0.099	0.075
	(0.49)		(0.72)	(0.70)	(0.68)
Share HHs w/ Sewer*Post	0.029		-0.044	-0.077	-0.069
	(0.12)		(0.13)	(0.13)	(0.14)
Share Pop. Age 0-4*Post	-0.45		0.43	0.51	0.64
	(0.47)		(0.59)	(0.56)	(0.54)
Log Pop.*Post	-0.0081**		-0.023***	-0.025***	-0.024***
	(0.0041)		(0.0061)	(0.0062)	(0.0062)
Share Pop. w/ Soc. Sec.*Post	-0.018		-0.095	-0.078	-0.042
	(0.079)		(0.12)	(0.12)	(0.12)
Avg. Yrs. Schooling*Post	0.012*		0.055***	0.059***	0.060***
	(0.0070)		(0.016)	(0.017)	(0.017)
Observations	319165	319165	319165	319165	319165
Region-Year Effects	State-year	Mun-year	Mun-year	Mun-year	Mun-year
Locality Effects	Y	Y	Y	Y	Y
Municipality Chars.*Post	Y	N	N	N	N
Hospital Effects	N	N	N	Y	N
Hospital-Year Effects	N	N	N	N	Y
Pre-Reform Mean (Near=1)	0.094	0.094	0.094	0.094	0.094

Notes: Columns (2)-(5) report regressions similar to Table 2, Panel A; Column (1) reports an alternative specification with municipality characteristics (listed in Appendix B.6) interacted with a Post (≥2009) dummy in place of municipality-year effects. See notes to Table 2 for details. Robust standard errors, clustered at the locality level, are in parentheses. *10% level, **5% level, ***1% level.

Table A.10. Share Live Birth, Hospital-Discharge Data

	Outcome: 1(live birth)				
	(1)	(2)	(3)	(4)	(5)
Near*Post	0.0041	-0.00026	0.0048	0.0043	0.0042
	(0.013)	(0.0094)	(0.011)	(0.011)	(0.011)
Mother's Age	0.015***	0.015***	0.015***	0.013***	0.013***
	(0.0021)	(0.0021)	(0.0021)	(0.0013)	(0.0013)
Mother's Age Squared	-0.00035***	-0.00035***	-0.00035***	-0.00032***	-0.00032***
	(0.000046)	(0.000046)	(0.000046)	(0.000030)	(0.000029)
1(1≤ Other ≤5)*Post	-0.039		-0.016	-0.0091	-0.012
	(0.027)		(0.037)	(0.036)	(0.038)
1(6≤ Other ≤10)*Post	-0.058		0.0020	0.023	0.038
	(0.038)		(0.069)	(0.069)	(0.076)
1(Other ≥11)*Post	-0.083**		0.076	0.072	0.10
	(0.037)		(0.078)	(0.078)	(0.085)
Share HHs w/ Water*Post	0.053		0.13*	0.096	0.080
	(0.063)		(0.066)	(0.059)	(0.061)
Share HHs w/ Elect.*Post	-0.071		0.11	0.064	-0.037
	(0.55)		(0.84)	(0.85)	(0.89)
Share HHs w/ Sewer*Post	-0.075		-0.13	-0.077	-0.073
	(0.086)		(0.096)	(0.088)	(0.094)
Share Pop. Age 0-4*Post	0.087		0.20	0.056	0.021
	(0.53)		(0.59)	(0.57)	(0.58)
Log Pop.*Post	0.0019		-0.0092	-0.0065	-0.0068
	(0.0043)		(0.0064)	(0.0063)	(0.0063)
Share Pop. w/ Soc. Sec.*Post	0.080		-0.12	-0.20	-0.20
	(0.11)		(0.15)	(0.14)	(0.16)
Avg. Yrs. Schooling*Post	-0.0022		0.021	0.021	0.024
	(0.0089)		(0.020)	(0.019)	(0.019)
Observations	359389	359389	359389	359389	359389
Region-Year Effects	State-year	Mun-year	Mun-year	Mun-year	Mun-year
Locality Effects	Y	Y	Y	Y	Y
Municipality Chars.*Post	Y	N	N	N	N
Hospital Effects	N	N	N	Y	N
Hospital-Year Effects	N	N	N	N	Y
Pre-Reform Mean (Near=1)	0.914	0.914	0.914	0.914	0.914

Notes: Columns (2)-(5) report regressions similar to Table 2, Panel A; Column (1) reports an alternative specification with municipality characteristics interacted with a Post (≥2009) dummy in place of municipality-year effects. See notes to Table 2 for details. Robust standard errors, clustered at the locality level, are in parentheses. *10% level, **5% level, ***1% level.

Table A.11. Low Birthweight Indicator, Birth-Certificate Data

	Outcome: 1(Birthweight $<$ 2.5 kg)			
	Hospital Type			
	MH (1)	Other public (2)	Private (3)	All (4)
Near*Post	0.052***	0.0020	0.0024	0.020**
	(0.014)	(0.019)	(0.015)	(0.0081)
Mother's Age	-0.0067***	-0.0096***	-0.0084***	-0.0078***
	(0.00059)	(0.00069)	(0.0013)	(0.00036)
Mother's Age Squared	0.00013***	0.00018***	0.00015***	0.00015***
	(0.000012)	(0.000015)	(0.000022)	(0.0000063)
1(1 $\leq$ Other Lead $\leq$ 5)*Post	0.012	-0.024	0.019	0.011
	(0.024)	(0.036)	(0.024)	(0.016)
1(6 $\leq$ Other Lead $\leq$ 10)*Post	0.025	-0.020	-0.015	-0.0035
	(0.038)	(0.041)	(0.031)	(0.023)
1(Other Lead $\geq$ 11)*Post	-0.11***	-0.071	0.049	-0.060**
	(0.038)	(0.048)	(0.039)	(0.024)
Share HHs w/ Water*Post	-0.034	0.067	0.016	0.0018
	(0.043)	(0.060)	(0.048)	(0.030)
Share HHs w/ Elect.*Post	0.75**	-0.17	0.13	0.18
	(0.34)	(0.22)	(0.47)	(0.23)
Share HHs w/ Sewer*Post	-0.21***	0.016	-0.033	-0.062
	(0.076)	(0.099)	(0.095)	(0.051)
Share Pop. Age 0-4*Post	0.93***	-0.12	0.012	0.27
	(0.29)	(0.37)	(0.41)	(0.20)
Log Pop.*Post	0.0060*	-0.0093**	0.0046	0.0023
	(0.0036)	(0.0044)	(0.0061)	(0.0026)
Share Pop. w/ Soc. Sec.*Post	-0.094	-0.11	0.026	-0.0064
	(0.077)	(0.078)	(0.092)	(0.049)
Avg. Yrs. Schooling*Post	0.0085	0.020*	-0.011	-0.000047
	(0.0083)	(0.011)	(0.0097)	(0.0053)
Observations	226458	187684	139818	553960
Locality Effects	Y	Y	Y	Y
Municipality-Year Effects	Y	Y	Y	Y
Hospital-Year Effects	Y	Y	Y	Y
Pre-Reform Mean (Near=1)	0.124	0.100	0.071	0.095

Notes: Table presents same regressions as Table 2 Panel B.1, but with more complete reporting of coefficients on locality characteristics.

Table A.12. Birthweight, Birth-Certificate Data

	Outcome: Birthweight (grams)			
	Hospital Type			
	MH (1)	Other public (2)	Private (3)	All (4)
Near*Post	-71.5***	28.6	-8.19	-23.5
	(23.6)	(33.4)	(27.7)	(17.4)
Mother's Age	22.3***	28.5***	20.7***	24.0***
	(0.83)	(1.26)	(1.58)	(0.95)
Mother's Age Squared	-0.34***	-0.47***	-0.32***	-0.38***
	(0.014)	(0.030)	(0.027)	(0.018)
$1(1 \leq$ Other Lead $\leq 5)$*Post	6.22	-60.3	-68.4*	-36.6
	(37.5)	(66.4)	(38.2)	(26.8)
$1(6 \leq$ Other Lead $\leq 10)$*Post	-53.0	-114.1	-69.8	-50.9
	(63.4)	(75.8)	(57.0)	(41.1)
1(Other Lead ≥ 11)*Post	74.5	-38.3	-84.4	25.0
	(57.1)	(84.5)	(61.5)	(43.8)
Share HHs w/ Water*Post	28.1	-144.2	-54.5	-9.81
	(60.5)	(88.3)	(95.4)	(46.4)
Share HHs w/ Elect.*Post	-689.1	-242.8	-1374.2*	-578.1
	(558.9)	(441.4)	(749.9)	(384.8)
Share HHs w/ Sewer*Post	192.6	-333.0**	165.1	79.7
	(139.2)	(156.8)	(168.6)	(86.1)
Share Pop. Age 0-4*Post	-1362.9***	-600.8	-1118.8*	-774.3**
	(486.6)	(619.9)	(667.1)	(345.5)
Log Pop.*Post	-3.92	20.1**	-8.67	-2.16
	(6.11)	(8.12)	(10.3)	(4.59)
Share Pop. w/ Soc. Sec.*Post	41.6	96.8	387.4***	106.2
	(130.7)	(131.5)	(140.4)	(89.4)
Avg. Yrs. Schooling*Post	-2.73	4.40	4.27	7.27
	(13.3)	(20.8)	(18.1)	(9.40)
Observations	226458	187684	139818	553960
Locality Effects	Y	Y	Y	Y
Municipality-Year Effects	Y	Y	Y	Y
Hospital-Year Effects	Y	Y	Y	Y
Pre-Reform Mean (Near=1)	3011.4	3078.8	3095.1	3068.3

Notes: Table presents same regressions as Table 2 Panel B.2, but with more complete reporting of coefficients on locality characteristics.

Table A.13. Low Birthweight Ind., Birth Certificates, Additional Mother Chars.

	Outcome: 1(Birthweight < 2.5 kg)			
	Hospital Type			
	MH (1)	Other public (2)	Private (3)	All (4)
Near*Post	0.052***	0.0014	0.0024	0.020**
	(0.014)	(0.019)	(0.015)	(0.0081)
Mother's Age	-0.0072***	-0.0088***	-0.0085***	-0.0079***
	(0.00065)	(0.00058)	(0.0011)	(0.00037)
Mother's Age Squared	0.00014***	0.00017***	0.00015***	0.00015***
	(0.000013)	(0.000012)	(0.000019)	(0.0000062)
Married	-0.0058	-0.018***	-0.013	-0.011***
	(0.0051)	(0.0063)	(0.015)	(0.0033)
Single	-0.0051	-0.010	-0.0040	-0.0066**
	(0.0057)	(0.0067)	(0.015)	(0.0032)
Civil Union	-0.0026	-0.014**	-0.010	-0.0074**
	(0.0056)	(0.0063)	(0.015)	(0.0030)
1st Live Birth	-0.0043***	-0.0031	-0.014***	-0.0065***
	(0.0015)	(0.0055)	(0.0037)	(0.0014)
2nd Live Birth	-0.0041***	-0.012***	-0.012***	-0.0093***
	(0.0015)	(0.0037)	(0.0033)	(0.00077)
Previous Birth Stillborn	0.011***	0.0098***	0.018***	0.013***
	(0.0022)	(0.0035)	(0.0033)	(0.0018)
Received Pre-Natal Care	-0.035***	-0.042***	-0.0059	-0.033***
	(0.0046)	(0.0067)	(0.012)	(0.0027)
7-9 Yrs Educ	0.00093	-0.0044*	-0.00063	-0.00076
	(0.0010)	(0.0024)	(0.0039)	(0.00091)
10+ Yrs Educ	0.0051***	0.0019	0.00033	0.0032**
	(0.0019)	(0.0031)	(0.0054)	(0.0014)
Observations	226458	187684	139818	553960
Locality Effects	Y	Y	Y	Y
Municipality-Year Effects	Y	Y	Y	Y
Locality Chars.*Post	Y	Y	Y	Y
Hospital-Year Effects	Y	Y	Y	Y
Pre-Reform Mean (Near=1)	0.124	0.100	0.071	0.095

Notes: Table similar to Table 2 Panel B.1, but with additional mother characteristics as controls. Summary statistics on additional mother characteristics are in Appendix Table A.3. Robust standard errors, clustered at the locality level, are in parentheses. *10% level, **5% level, ***1% level.

Table A.14. Birthweight, Birth Certificates, Additional Mother Characteristics

	Outcome: Birthweight (grams)			
	Hospital Type			
	MH (1)	Other public (2)	Private (3)	All (4)
Near*Post	-72.0***	29.2	-8.25	-23.6
	(23.7)	(33.3)	(27.7)	(17.5)
Mother's Age	19.9***	25.8***	20.4***	22.2***
	(0.81)	(0.74)	(1.37)	(0.54)
Mother's Age Squared	-0.31***	-0.42***	-0.31***	-0.35***
	(0.013)	(0.019)	(0.024)	(0.012)
Married	37.1***	37.3***	23.9	35.0***
	(13.5)	(12.2)	(16.2)	(7.16)
Single	24.8	16.4	0.073	18.0**
	(16.6)	(13.7)	(16.0)	(8.69)
Civil Union	24.2	25.8**	18.2	23.8**
	(17.9)	(12.6)	(14.9)	(9.94)
1st Live Birth	-8.18**	-0.10	13.5*	0.42
	(3.84)	(10.8)	(8.03)	(1.44)
2nd Live Birth	6.32***	23.6***	12.2**	13.7***
	(2.18)	(4.93)	(4.80)	(1.18)
Previous Birth Stillborn	-7.92**	-3.97	-24.7***	-11.6***
	(3.40)	(5.65)	(5.14)	(3.18)
Received Pre-Natal Care	63.8***	60.0***	4.23	56.5***
	(7.05)	(17.3)	(22.7)	(3.20)
7-9 Yrs Educ	-0.98	1.65	-10.2**	-1.93*
	(1.83)	(2.83)	(4.77)	(1.04)
10+ Yrs Educ	-11.4**	-9.64**	-14.8**	-11.5***
	(4.76)	(4.31)	(6.95)	(2.54)
Observations	226458	187684	139818	553960
Locality Effects	Y	Y	Y	Y
Municipality-Year Effects	Y	Y	Y	Y
Locality Chars.*Post	Y	Y	Y	Y
Hospital-Year Effects	Y	Y	Y	Y
Pre-Reform Mean (Near=1)	3011.4	3078.8	3095.1	3068.3

Notes: Table similar to Table 2 Panel B.2, but with additional mother characteristics as controls. Summary statistics on additional mother characteristics are in Appendix Table A.3. Robust standard errors, clustered at the locality level, are in parentheses. *10% level, **5% level, ***1% level.

Table A.15. Summary Statistics, Tracts Near Binding vs. Non-Binding Plants

	Tracts near "binding" plants (1)	Tracts near "non-binding" plants (2)	Difference (3)
Total population	3,798	3,644	154
	(1,331)	(1,595)	(208)
Percent non-Hispanic White	24.46	44.61	-20.15
	(34.12)	(32.09)	(5.19)
Percent non-Hispanic Black	5.66	17.37	-11.71
	(12.27)	(24.30)	(2.11)
Percent Hispanic	67.88	26.56	41.32
	(40.10)	(29.37)	(6.01)
Median household income (dollars)	39,291	46,180	-6,888
	(7,158)	(24,221)	(1,518)
Median house value (dollars)	282,691	288,947	-6,255
	(143,842)	(195,525)	(22,814)
Fertility ratio	3.13	3.87	-0.74
	(3.34)	(4.58)	(0.53)
Percent unemployed	6.23	6.81	-0.58
	(3.00)	(3.74)	(0.47)
Percent 25+ yrs with < HS degree	46.00	22.66	23.33
	(18.79)	(15.23)	(2.83)
Number of tracts	46	486	

Notes: Data are tract-level estimates from the 2010 American Community Survey 5-year estimates. "Near" means $\leq$ 2 mi., using ACS-reported longitude and latitude for census tracts. "Binding" plants have pre-2008 average lead concentrations over nearby monitors above 0.15 $\mu g/m^3$. "Non-binding" plants are other lead-emitting plants. For further details, see Appendix D. Columns (1)–(2) present means across tracts, with standard deviations in parentheses. Column (3) presents differences in the means, with standard errors of the differences in parentheses. "Percent 25+ years with < HS degree" refers to percent of the population aged 25 years or older that has less than a high school degree.