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

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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

[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.

[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, crime, and mortality among the elderly; see e.g. Reyes (2007), Nilsson (2009), Aizer et al. (2018), Rau et al. (2015), Billings and Schnepel (2018), Grönqvist et al. (2020), Clay et al. (2021), and Hollingsworth and Rudik (2021). 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 II 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 (SEMARNAT, 2011). The url is no longer active. The exact locations of the authorized plants were identified from the SEMARNAT battery-recycler list, the RETC (SEMARNAT, 2013), 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 II, 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 (U.S. Census Bureau, 2015b). 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.[5] We have corrected the raw reported values using commodity-specific statistical corrections provided by the Census Bureau (U.S. Census Bureau, 2015a). 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) (Secretaría de Salud, 2015a) 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

[5] 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. (forthcoming). Unfortunately, it appears that battery recyclers typically do not import the ULABs directly and hence do not show up in the customs records.

data were also downloaded from the Ministry of Health website in two stages, for 2008–2013 on July 21, 2015, for 2014 on Dec. 1, 2017, and for 2015 on July 15, 2018 (Secretaría de Salud, 2015b). 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, 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*) (INEGI, 2018).

The following locality characteristics are taken from the locality-level statistics of a 2005 population enumeration (*El Conteo de Población y Vivienda 2005*) from INEGI (2005a).[6]

- *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.

[6]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, 2005a)*.

- *Infant mortality.* The number of deaths of young children under the age of 1 per 1000 births. Source: INAFED (2005b).

- *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, 2005a)*.

- *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, 2005).

- *Homicides.* Number of homicides, calculated from homicide data provided by INEGI (2014).

- *Labor Income per Capita.* Average yearly earned labor income, calculated from 10% sample of INEGI (2000), made available through Minnesota Population Center (Minnesota Population Center, 2020).[7]

- *Municipality Tax Revenue per Capita.* Municipality-level tax collection available from the INEGI's System of Municipal Accounts (*Sistema de Cuentas Municipales*) (INEGI, 2005b).

[7]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.

- *Gini Index*. Gini Index for 2005. Source: CONEVAL (2005b).

C Analysis of U.S. Exports

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

As mentioned in Section III.III.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.[8] 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.[9] 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 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

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

[9] 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.

and Schott (2012), map each HS10 codes into a single NAICS 6-digit sector.[10] 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.

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, 2010a) to characterize this difference. We use the ACS 5-year estimates. We also used the Census county centroid data

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

to obtain FIPS information (U.S. Census Bureau, 2010b). 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 U.S. Census Bureau (2010c). 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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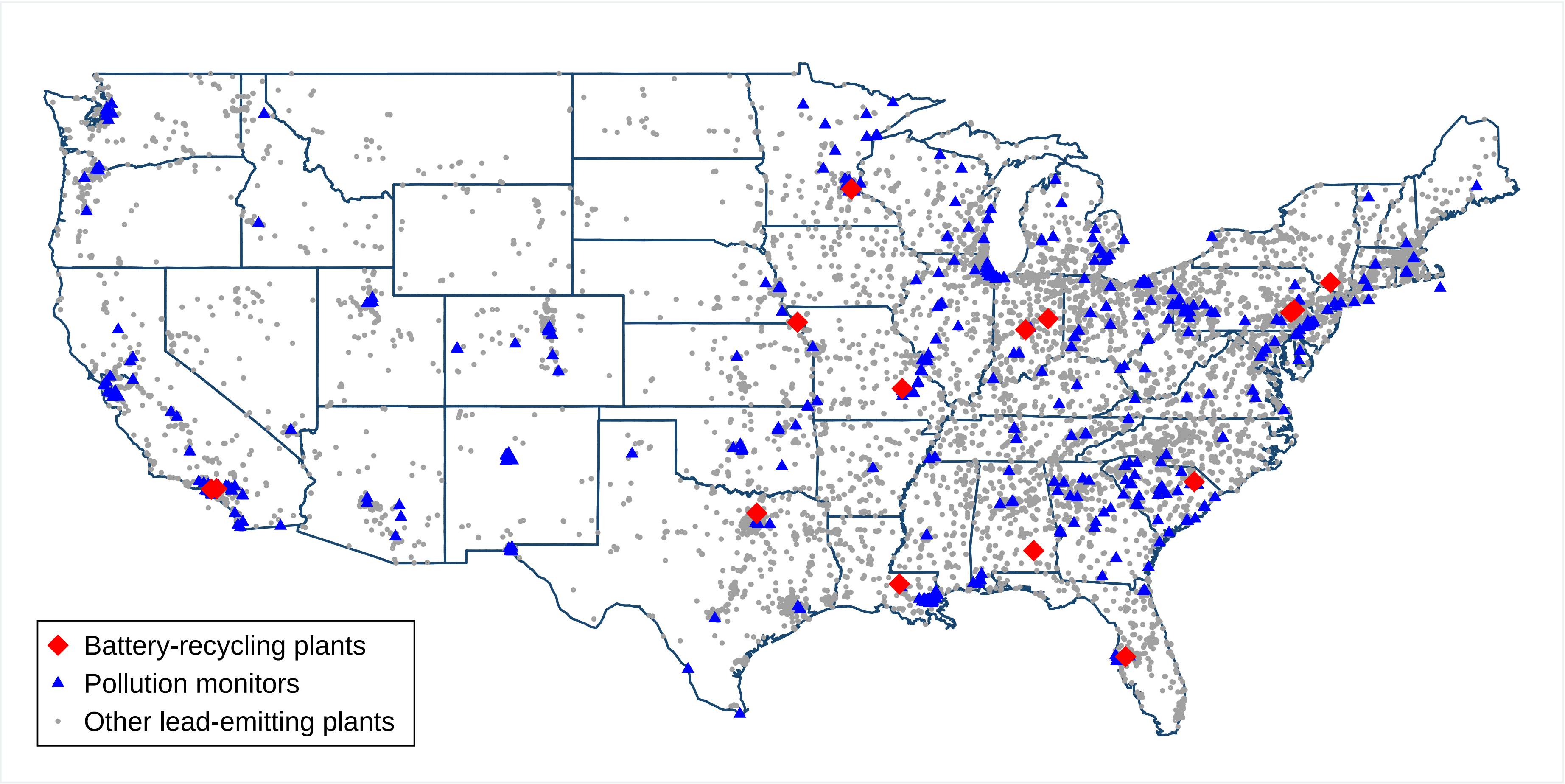
Figure A.1. Locations of Plants and Monitors in the U.S.

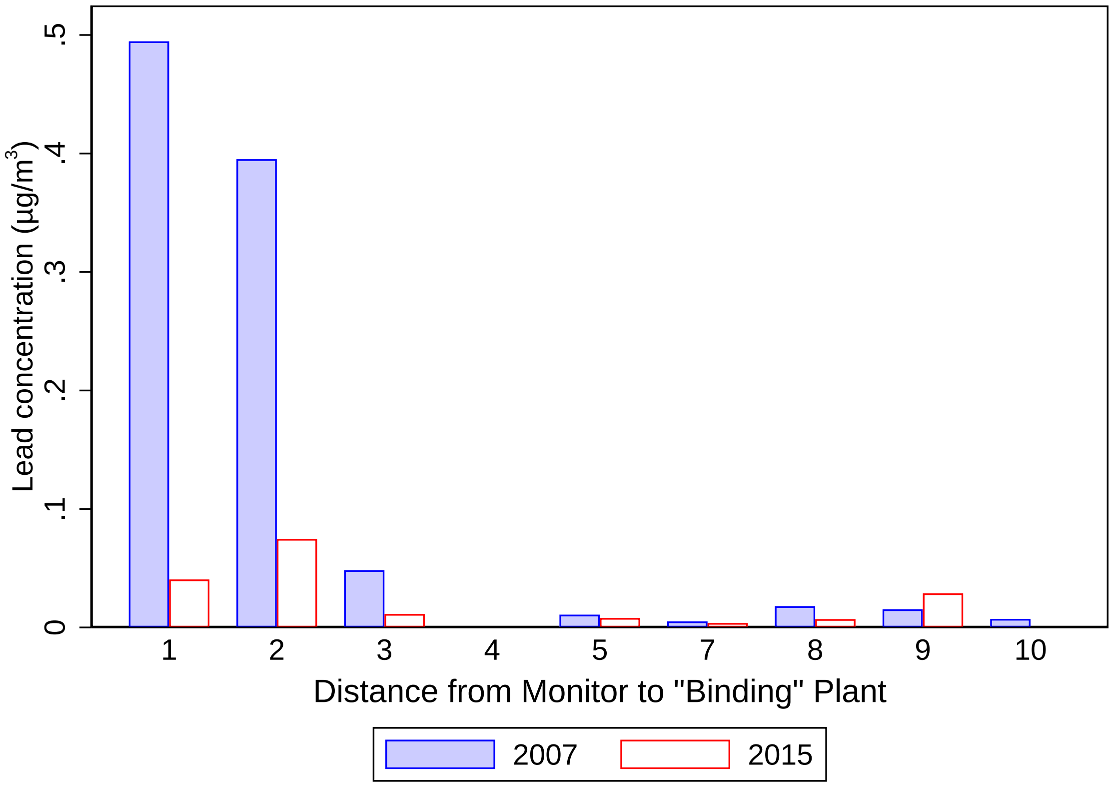


Notes: This map shows the locations of battery recycling plants, other lead-emitting plants, and pollution monitors maintained by the U.S. Environmental Protection Agency that monitor lead active in our study period.

Figure A.2. Locations of Plants in Mexico

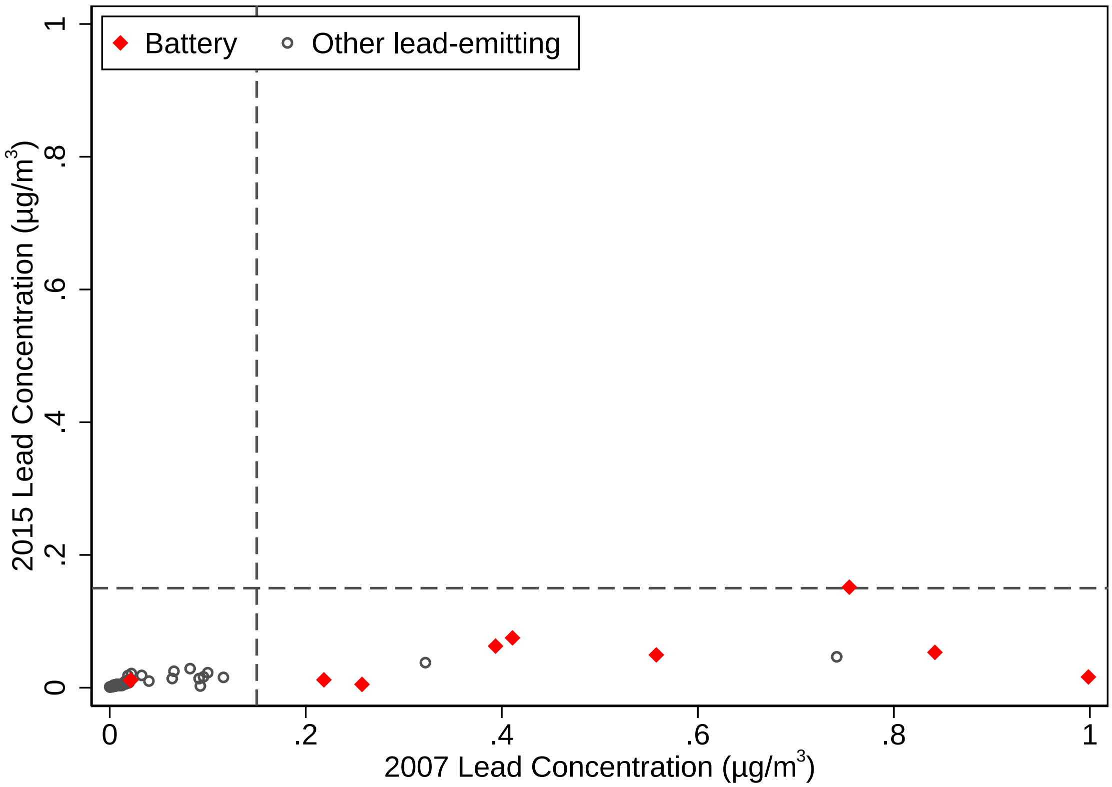
Notes: This map shows the locations of 26 Mexican battery-recycling plants constructed from CEC (2013) and the Mexican *Registro de Emisiones y Transferencia de Contaminantes* (RETC). Several plants are located close to one another and are difficult to distinguish visually.

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



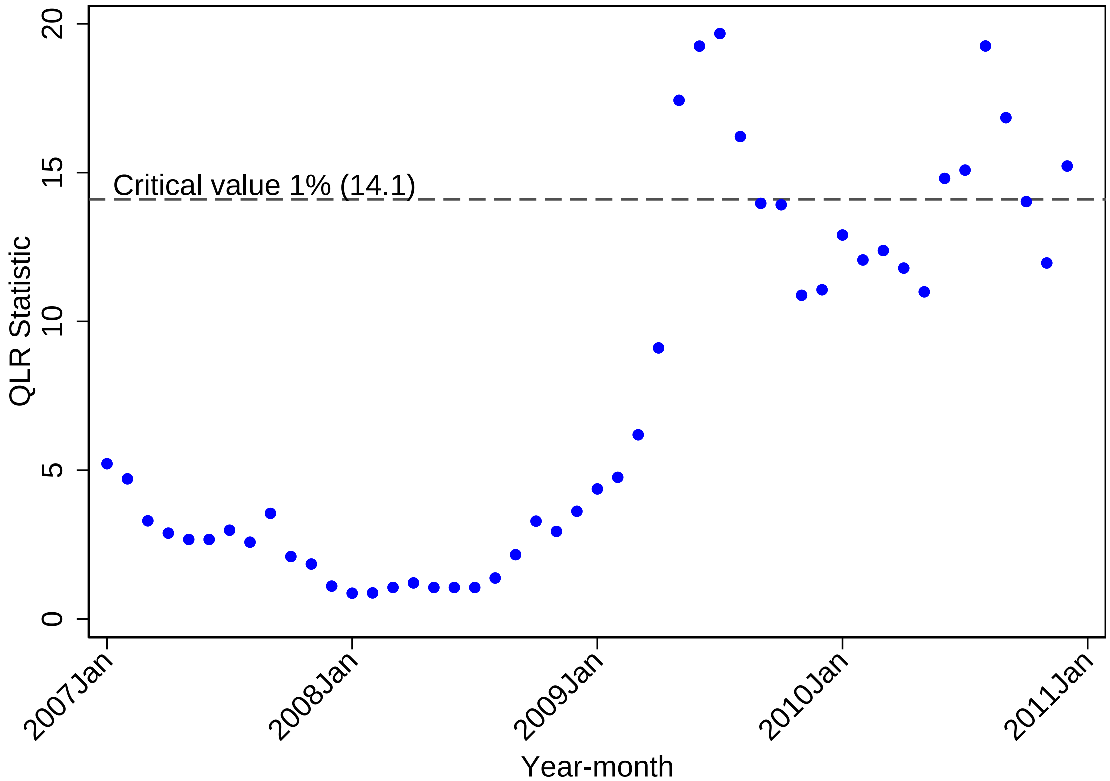
Notes: A plant is considered to be "binding" if average lead concentration at nearby monitors ($\leq$ 2 mi.) is above the new standard (0.15 $\mu g/m^3$) prior to 2009 reform. The figure shows average ambient lead concentrations at monitors by 1-mile distance bin from such plants.

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



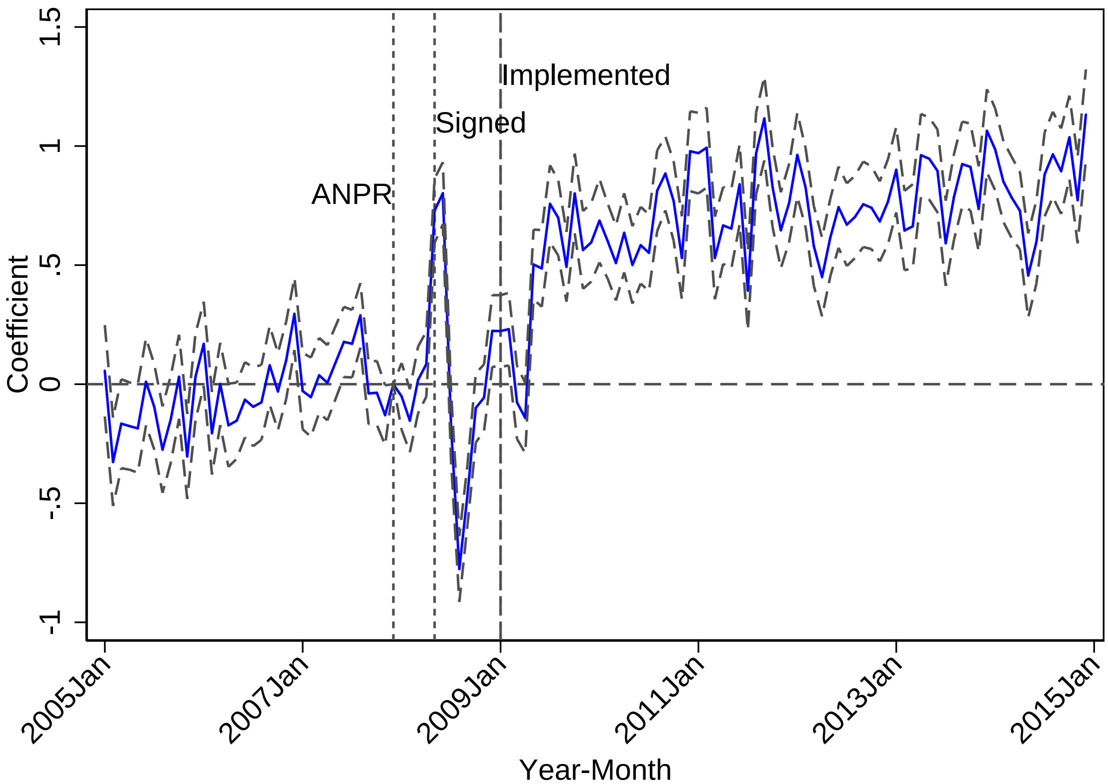
Notes: The figure plots average lead concentrations at the plant level, where averages are calculated over all nearby (≤ 2 mi.) monitors measuring lead for which a given plant is the nearest lead emitter. The dashed lines indicate the revised air-quality standard (NAAQS) for lead (0.15 $\mu g/m^3$).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

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



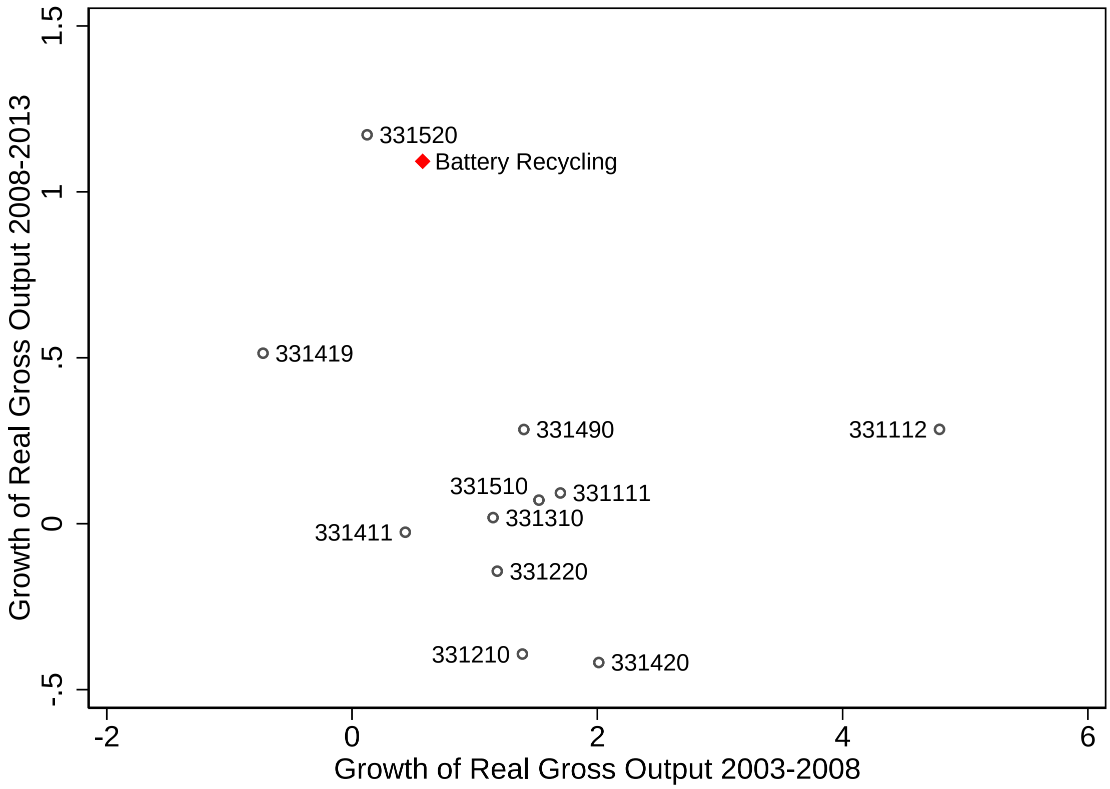
Notes: The figure above presents the Quandt Likelihood Ratio (QLR) statistics for a potential trend break in months between 2007 and 2010 using the sample of 2004–2014. The asymptotic critical value at the 1 percent significance level is provided by Andrews (1993, 2003).

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



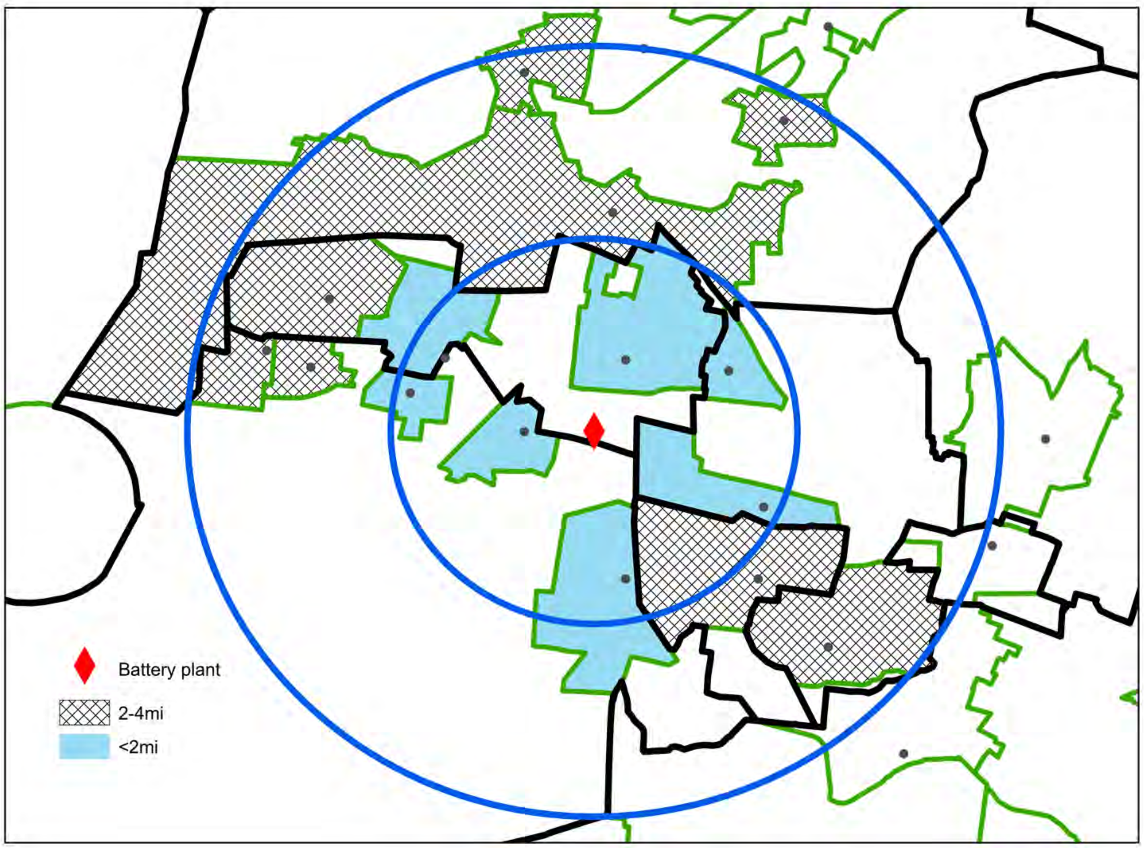
Notes: Figure reports estimates of β_τ from equation (A2). Sample includes exports for HS10 products that map to NAICS 331 (Primary Metal Manufacturing) plus battery recycling (which sums HS10 categories 8548100540, 8548100580, and 8548102500). The gray dotted lines indicate 95% confidence intervals.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

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



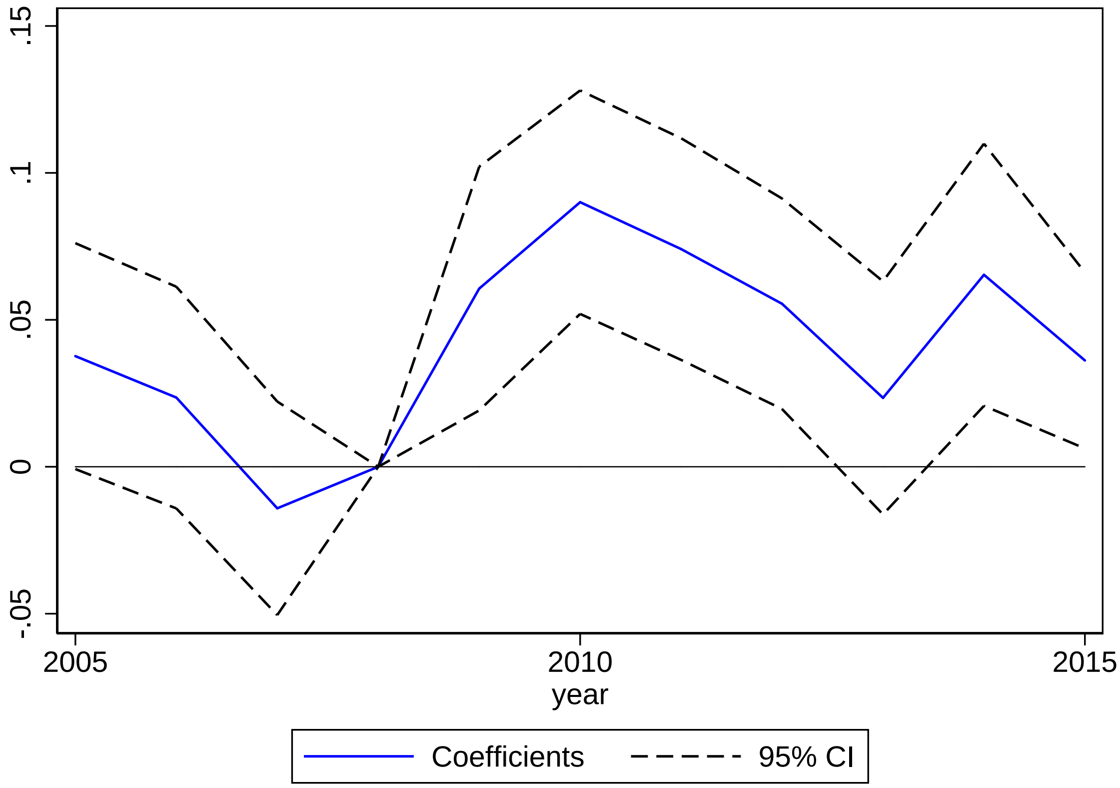
Notes: Output by 6-digit industry is taken from the 2004, 2009, and 2014 Economic Censuses (data for 2003, 2008, and 2013), for North American Industry Classification System (NAICS) sector 331 of (Primary Metal Manufacturing). Growth of output is defined as $((y_t - y_{t-1})/y_{t-1})$. The detailed 6-digit 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)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	≤ 2mi	2–4mi	≤ 2mi	2–4mi	≤ 2mi	2–4mi	≤ 2mi	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 ≥ 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.