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Environmental Regulation in Mexico

EVIDENCE FROM INSPECTIONS AND FINES OF MAJOR TOXIC POLLUTERS

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Abstract

In the Global South, local pollution problems have been studied mostly in the context of environmental inequity. This is the first paper to focus on regulatory actions taken by the Mexican environmental protection agency and obtain conservative estimates on the deterrence impact of fines imposed on the major toxic facilities nationwide. We interpret our results with caution as higher self-reported toxic discharges does not trigger inspections and sanctions by the regulators. Rather fines due to non-compliance with the measurement and reporting protocols could be perceived as a credible signal to international (and national) consumers and buyers as not stewards but laggards in corporate environmental responsibility.

Keywords: Deterrence, Environmental Compliance, Inspections and Fines, Developing Countries, Global South
JEL CODES: K23, L51, Q52, Q53

Resumen

En el Global South los problemas de contaminación local se han estudiado principalmente en el contexto de la desigualdad ambiental. Este es el primer documento enfocado en las medidas regulatorias tomadas por la agencia mexicana de protección ambiental. Nuestro objetivo es obtener estimaciones conservadoras sobre el efecto disuasorio de las multas impuestas a las principales instalaciones que emiten sustancias tóxicas en todo el país. Interpretamos nuestros resultados con cautela porque que no hay relación directa entre las descargas tóxicas (auto-declaradas) y las inspecciones, de hecho, las emisiones elevadas no generan inspecciones o sanciones por parte de los reguladores. Más bien, las multas se deben al incumplimiento de los protocolos de medición. Estos informes de incumplimiento pueden percibirse como una señal directa para que los consumidores (nacionales e internacionales) evalúen la responsabilidad ambiental corporativa de estas industrias, tomen decisiones administrativas de fomento o boicot y eviten así formas rezagadas de responsabilidad ambiental.

Palabras claves: disuasorio ambiental, cumplimiento ambiental, inspecciones y multas, países en desarrollo, Global South

Introduction

Regulation of environmental pollution such as air, water (surface and groundwater), and land cannot be effective without appropriate monitoring and enforcement of these regulations. Much of the literature has debated about relative efficiency of emission standards based on command-and-control (CAC) approach versus pollution taxes, emission fees or trading programs based on market-based incentives (MBI) approach (Blackman *et al*., 2018). Environmental pollution control in the U.S. illustrates implementation of both CAC regulations for air and water pollution across the nation and MBI instruments like cap-and-trade for more regional problems of acid rain and state level for carbon markets. Both instruments though rely on self-reported emissions of the regulated entities; therefore, assessing its validity through adequate inspections and follow-up enforcement actions are crucial components of any pollution control policy irrespective of its regional, national or global scale.

Monitoring and enforcement actions can be quiet time consuming and costly procedures Shimshack (2014). Environmental inspections in the U.S. range from low intensity activities such as visual confirmation of abatement equipment to maintenance, sampling, and reporting procedures and even sampling emissions at the plant. Subsequently, enforcement actions are based on severity of violation and compliance history of the facility. Usually, they begin with administrative orders and might end in financial penalties and closure of operation, following civil and criminal litigations. Monitoring and enforcement in developing countries are mired with problems of institutions and limited budget leading to pervasive regulatory capture. Informal regulation or community pressure is expected to be strong is such bleak regulatory environments (Pargal and Wheeler 1996 found such evidence in Indonesia). Policy makers in countries like Mexico turn to yet another (third) instrument for improving environmental performance that of voluntary mechanisms such as obtaining Clean Industry Certificates with limited effectiveness (Blackman, 2012, 2010; Blackman *et al.*, 2010).

The objective of this paper is to study what factors determine monitoring and enforcement actions such as fines imposed on major toxic polluters in Mexico and whether such enforcement actions have any deterring impact on environmental pollution. Unlike the monitoring protocol of environmental protection agencies in developed countries, inspection and enforcement in Mexico have a much more limited role to play. For air emissions, inspectors usually engage in visual inspection of equipment and perhaps operation (Profepa, 2013). For water and other polluting activities, inspectors check documentation on permits (whether they are current, and payments made) and measurement records going back for past three years (whether samples were sent to accredited labs for measurement and recorded). Enforcement actions such as pecuniary penalties (fines) are suspected to have limited deterrence effect as they are often strongly appealed in a court of law by polluters and ultimately end up paying a very small fraction or none of the original fined amount (Escobar and Chavez, 2013).

In this paper, we consider a non-regulatory database that of toxics pollution registry in Mexico and answer two vital questions on environmental policy: 1) What factors determine monitoring and enforcement actions against major polluters? and 2) Do self-reported pollution decline as a result of the enforcement actions such as fines imposed on monitoring and enforcement protocol by regulators? We collect a large dataset on regulatory inspections and enforcement activities such as monetary fines for all plants that were visited by regulatory officials from 2000 onwards. Previous literature on Mexico, utilized inspections (compliance with reporting and monitoring protocols) and fines as proxies for environmental performance in the absence of data on emissions. In this paper, we include plant-level self-reported pollution data obtained from the toxic pollution registry system from 2004 onwards when Mexico implemented mandatory reporting. We investigate what factors lead to higher inspections and sanctions against major toxic polluters and whether enforcement actions such as fines result in improved compliance by reducing pollution. Our panel data specifications include socioeconomic and demographic controls.

Our inspections and fines models show that regulation in Mexico is effective as inspections or complaints are aptly followed up with financial penalties. Overall, past inspections are followed up with verification visits (higher probability of inspections by 6 percentage points) and past fines imposed are enforced by raising the probability of follow-up visits by 8 percentage points (for chromium). Past inspections lead to higher probability of being fined by 2 percentage points and past fines lead to higher probability of current fines by 3 percentage points. In monetary terms, these translate to 439 and 589 dollars in real terms, respectively. Other pollutants' estimated marginal effects are very close. Socioeconomic factors are less important in influencing regulatory activities. In particular, we find no evidence of regulators addressing environmental justice concerns by concentrating their efforts on poorer, more marginalized neighborhoods. Densely populated areas on the other hand experience fewer inspection visits and enforcement actions like fines, by 0.6 and 0.2 percentage points respectively, most likely due to higher concentration of manufacturing activities in such areas.

Our environmental pollution models show that past fines reduce current pollution reported between 25% and 37% for lead, cadmium, chromium, nickel and cyanides discharges. Past inspections on the other hand result in higher self-reported discharges in the current year, between 4% and 25% for the same five pollutants, but statistically significant only for the highest estimate. We conclude that enforcement actions on failure to demonstrate adequate emissions measurement and record-keeping on samples going back up to three years, obtaining and renewing required permits, equipment installation, etc. are perceived as bad public image among consumers as they are widely publicized in the news media.[1] The role of inspections is that of providing guidance to the plants on emissions measurement, reporting and improving self-reported pollution protocol followed by the environmental personnel of firms.

This is the first paper to investigate whether monitoring and enforcement actions improve environmental performance of major toxic polluters in Mexico. The only other study that looks at determinants of monitoring and fines is that of Escobar and Chavez (2013) for air emissions in Mexico City. Our focus is more comprehensive as we incorporate all types of inspections programs like high risk activities, hazardous waste, and environmental impacts. Toxic waste comprised about 51% of all visits by inspectors as seen in the monitoring and enforcement database obtained for the entire country and from 2000 to 2016. Another contribution is that the authors mention that in the absence of self-reported emissions, they are able to observe environmental compliance only as a result of inspections conducted on the plants.[2] In this paper, we do not limit ourselves to this proxy for compliance status that is not frequently observed; instead we match the inspections and fines data to individual toxics generating plants that are obligated to report their emissions into air, water, land and sewage disposal etc. Hence, we are able to document whether *any* regulatory activity improve plant level environmental compliance by reducing their toxic pollution discharges into the environment. In addition, our models include detailed data on socioeconomic and demographic characteristics that control for plants' expectations on affected communities' preferences for environmental protection or local employment generation benefits.

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[1] Perla, M. (2018, February, 18th), Profepa multa a KIA Motors por más de 7 millo de pesos, *El Universal*. Retrieved from: https://www.eluniversal.com.mx/nacion/sociedad/profepa-multa-kia-motors-por-mas-de-7-millones-de-pesos; Montoya, JR. (2018, November, 14th). Multa Pofepa con 3.7 millones de pesos a termoeléctrica de CFE, La Jornada. Retrieved from: https://www.jornada.com.mx/ultimas/2018/11/14/impone-profepa-multa-de-3-7-millones-de-pesos-a-termoelectrica-de-cfe-1641.html; Profepa realiza multas en Tabasco por casi 30 millones de pesos, (2018, December, 4th), La Verdad. Retrieved from: https://laverdadnoticias.com/ecologia/PROFEPA-realiza-multas-en-Tabasco-por-casi-30-millones-de-pesos-20181204-0143.html.

[2] The five possible compliance statutes are "Priority Attention", "Temporary Closure", "Urgent Measures", "Minor Infractions" and "Full Compliance".

BACKGROUND AND LITERATURE

Empirical Evidence on enforcement and deterrence

Regulatory interventions such as inspections and enforcement activities have been shown to improve environmental performance in developed countries such as the U.S. (Shimshack, 2014). Most of these papers focus on conventional air and water pollutants rather than toxic pollutants; the latter is the only source of plant level pollution data available in Mexico. The Toxics Releases Inventory (TRI) in the US (as well as Mexico's toxics registry) serves as a (mandatory) public information disclosure mechanism and are not regulatory databases like the Clean Water Act (CWA) and the Clean Air Act (CAA) for conventional pollutants. For an insightful survey of the evidence on effectiveness of the major environmental regulations see Gray and Shimshack (2011).

Availability of plant specific data on types of inspections and enforcement actions meant that detailed measures of regulatory pressure could be constructed. Specific deterrence refers to compliance efforts of a plant on account of inspections and enforcement conducted against itself. General deterrence refers to compliance efforts in response to inspections and enforcement conducted on plants in the same industry and state. Inspections and enforcement actions are usually lagged due to the targeting behavior of regulatory authorities based on the environmental performance of plants (Harrington, 1988; Helland, 1998). A broader set of studies include both direct regulatory channels of improving environmental compliance and indirect (through community) channels, e.g. citizen complaints, of pressure on regulators. For example, environmental preferences of state level constituents are included in the inspections and enforcement models as well as plant level pollution models to capture community pressure in Gray and Shadbegian (2004).

In Latin America, we could find only one study in Uruguay (Caffera and Lagomarsino, 2014) that investigated effectiveness of formal regulatory measures on self-reported biological-oxygen-demand discharges into water. For Mexico, the question of environmental deterrence has not been addressed primarily due to lack of measures of environmental performance. The remaining evidence comes from Brazil.

Seroa de Motta (2006) uses survey data of large manufacturing plants in Brazil, for the year 1997, to conclude that regulatory sanctions influence the environmental practices adopted by these plants. Pressure from communities and NGOs are also important in explaining environmental performance of manufacturing firms in Brazil. Feres and Reynaud (2012) find that both formal regulation directly through inspections and sanctions and informal regulation indirectly through community pressure influence environmental performance of polluters in Sao Paolo. They capture informal regulation by using the count of citizen complaints about pollution at a given plant or in a given location and the number of meetings organized with environmental NGOs, local community or political representatives.

To circumvent the costs of monitoring and enforcement of CAC regulations, the most famous examples from Latin America are actually MBI like discharge fees in Colombia and the Emissions Compensation Program in Chile (a trading program that effectively got implemented as emissions standards as the individual sources held on to their emissions capacity permits). Unfortunately, experience shows that weak regulatory capacities plague cost effective implementation of these environmental regulations (Blackman *et al*., 2018). In the context of widespread violations, discovered in environmental audits, Palacios and Chavez (2005) find that compliance with the air pollution trading program in Santiago, Chile is driven by plant specific factors and areas with higher population density have lower probability of compliance while income of the neighborhood exerts higher compliance. In Briceno and Chavez (2010), they find that enforcement and control actions (like sampling inspections) taken by the local corporation of Corpochivor, Colombia leads to lower self-reported levels of BOD and TSS. However, enforcement and monitoring acitivities have no influence on final payment of the discharge fees.

Yet another famous example from a developing country is China's pollution levy system. Recent studies such as Lin (2013) find use plant level panel data and instrumental variable to avoid inspections and environmental performance decisions that are simultaneously determined. Surprisingly, they find that inspections are effective for verifying plants' self-reported pollution but not for improving performance by reducing their pollution.

Environmental Inspections and Enforcement in Mexico

Regulation of industrial pollution in Mexico has been implemented by a two-fold approach of first through command-and-control utilizing instruments of inspections and enforcement through sanctions, and second through voluntary initiatives by manufacturers that invest in pollution abatement in order to comply with standards set by third party environmental audits (Blackman ?). Profepa (Procuraduría Federal de Protección al Ambiente) is the agency in charge of enforcement and inspections of all polluting facilities subject to Mexico's General Law of Ecological Equilibrium and Environmental Protection (Ley General de Equilibrio Ecológico y Protección al Ambiente, LGEEPA).

Monitoring and enforcement activities are conducted by state-level regulators under federal oversight and supervision (Profepa, 2016). The Profepa inspections programs were under: high risk activities, toxic waste management, and land, air (fixed sources) and water pollution. Per their program of annual visits, they categorize plants from major to minor environmental impact (Camacho, 2016). For example, inspections are targeted towards plants that are in petrochemicals, chemicals, and metals processing sectors that are among the top six of their 32 impact classifications. Escobar and Chavez (2013) also find that regulatory efforts are directed towards larger industries (and hence more polluting) as well as in poorer and denser neighborhoods. However their sample covers only conventional air emissions in Mexico City.

The wider policy literature documents the apparent ineffectiveness of the command strategy “which is usually limited to surveillance of the aspects that are regulated [page 5 Alvarez-Larrauri and Foge,l 2008]” The enforcement agency of the environment secretariat, Profepa, simply did not have the resources to measure emissions directly (Foster and Gutierreez, 2010)). It is no surprise then that most of the economics literature on Profepa has focused on the evaluation of its voluntary environmental regulation program known as the Clean Industry certificates (Industria Limpia in Spanish). The overwhelming evidence from Blackman et al (2010, 2012) and is that plants seek out audits to get these environmental certificates primarily to access the synergies of two years’ inspections relief from Profepa as well as reputation as environmental stewards in Mexican manufacturing. However, long run compliance was not improved as plants that graduated from the program were not fined at lower rates than the remaining firms that did not enroll in the program. Most of these studies utilize Profepa fines as proxies for direct measures of environmental performance (Blackman and Guerrero, 2012). Blackman and Kildegaard (2010) utilize plant level data on regulatory inspections as a proxy for CAC regulations on wastewater discharges and find it has no influence of adoption of clean technologies for small and medium leather tanneries in Leon, Guanajuato.

We fill this gap in the literature by linking Profepa monitoring and enforcement activities to self-reported pollution by toxic polluting plants in Mexico. Dasgupta *et al.* (2000) is the only study to link inspections with adoption environmental management practices from a survey on Mexican firms in 1995. Given concerns of strategic underreporting of pollution found in similar Latin American countries any positive deterrence effect of Profepa inspections and fines would provide conservative estimates of its actual impact in improving environmental performance. We believe this is an important contribution to the regulatory literature in developing countries in the face of standard concerns of regulatory capture and bureaucratic forces operating in a developing country context.

DATA

We obtain inspections and fines data for all industries and businesses in Mexico from 2000 onwards. In order to include the data on formal regulatory actions, such as inspections and fines, for our pollution model, we had to manually match the plants in the Profepa database with the plants in the RETC database. Based on industry names, addresses, and other locational information, we were able to identify about a third of our plants in the pollution reports database with formal inspections and fines database. In addition we obtain detailed socioeconomic and demographic data on the marginalization index and population density of local populations from the Conapo database Mexico National Population Council (Consejo Nacional de Población, Conapo). This summary indicator capturing health, education, and housing conditions, among others, has been used in previous studies on Mexico (Escobar and Chavez, 2013).

Profepa data

We obtained detailed data on plant name, address, type of facility, inspections program, type of inspection, outcome of visit, final resolution and fines imposed through a Transparency request. Each plant is subject to specific regulations, depending on its activity. During the visit to the plant, the inspector checks the records of the plant that support its compliance with all the environmental norms that apply (for example, that an accredited lab has measured the discharges), and inspects visually some aspects. But, the protocol does not call for the inspector to take any sample. Then the inspector assesses if the plant meets the standards that is recorded as the outcome of the visit. These categories are: no irregularities, minor irregularities, urgent measures to be taken, priority attention, or temporary (partial or total) closure of operation. But that result is not the final outcome. All the evidence collected by the inspector is thereafter evaluated by other Profepa officials, who decide if the plant is meeting all the criteria. The various actions taken under final resolution are: closure of administrative record with no measures required, agreement to undertake measures to get back into compliance, sanctions. Between the visit and the final resolution several months can pass. The fines are calculated on the basis of the final resolution. From the data obtained, we were unable to verify whether plants were closed permanently as a final outcome of the enforcement actions.

We examine inspections and fines data from 2000 to 2016. State inspectors conduct inspections and impose fines based on violations under different programs. There are various programs under monitoring activities ranging from wildlife protection to coastal zone conservation. The prominent ones are related to industrial activities including toxic residuals, high risk activities, emissions into air, land, biological residuals, and environmental impact. Toxic waste or residuals is the largest inspections program with 51% of the visits between 2000 and 2016. High risk activities comprised 10% of all visits, land contamination and air emissions 9% each, biological residuals (8%) and environmental impact (5%) were the other major industrial inspections programs.

Typically, inspections are scheduled for annual visits but an industry may be visited more than once in the same year, based on whether the initial visit arose out of regular monitoring or due to emergency or citizen complaints. Following initial visits, there are verification visits after which firms are obligated by law to take measures to get back into compliance or sanctions typically fines are followed as resolution to administrative actions of enforcement. Between 2000 and 2016, Profepa conducted 114,174 visits of which 57% were regular inspection activities or initial visits, 32% were follow up verification visits, about 7% citizen complaints and the remaining 4% emergencies. On average, Profepa conducted about 7000 annual visits not differentiating between regular inspections and verification and complaints.

Next, we explore heterogeneity across states. As expected, the highest frequency of visits was in metropolitan cities and states with large industrial clusters. Of the 32 states, visits to industries in the Mexico City Metropolitan Area (MCMA) comprised 11% of all visits during the period examined, around 5% of all visits were for industries located in Chihuahua, Estado de Mexico, Nuevo Leon, Tamaulipas, Puebla and Baja California. Looking at the type of visits, visits arising out of citizen complaints are higher in states with resources and/or more educated and metropolitan communities. For example, the highest percentages are in the center of the country with Aguascalientes (19%), San Luis Potosi (17%) Zacatecas (11%), Guanajuato (10%), Baja California (14%) (proximity to US), Nuevo Leon and Jalisco (13%) including Monterrey and Guadalajara (respectively) and states neighboring the capital like Mexico State (11%), the MCMA (10%), and Queretaro (9.5%). On the other hand, visits arising due to emergency events like leaks and spills were highest in poorer states like Veracruz (19%), Oaxaca (16%), followed by Tamaulipas Guanajuato and San Luis Potosi with averages around 8 to 7%.

Of the total inspection visits, on average plants got fined about 30% of the times every year. From the data, plants can be fined more than once within a year, under different inspections program violations and the amount fined might be identical under all programs. For our main results, we aggregate fined amounts since the main purpose of these variables is to capture the deterrence effect on pollution. Recall that the fined amount themselves can be appealed by the plant so we try to capture deterrence based on the adverse public image created in the news media. (Saha and Mohr, 2013).

The fines data exhibit considerable variability in terms of pecuniary sanctions across years; only a few manufacturers are fined with significant penalties. The range varied between less than a dollar and over 35,000 dollars. All fines imposed as the final resolution are converted to 2010 dollars. On average, fines were 58 dollars with only 5% of the fines higher than 150 dollars. Recall that these fines are due to failure to comply with emissions equipment installation or reporting records or related measurement protocols rather than on actual emissions. In 2004, the number of fines above 5000 dollars was 14 (chemical, automotive and beverage producing facilities) and the only other year with five fines imposed was 2015. We speculate that the June 2004 mandatory reporting on toxics pollution might be the reason why polluters took time to take measures for the new regulation and hence fined. Subsequently, the reduction in fines greater than 5000 dollars could be due to improving protocols for emissions measurement and reporting or adopting voluntary approaches such as environmental certificates to avoid inspections and fines burden for two years.

The Profepa database does not contain systematic categorization on the sector of each plant either inspected or fined even though it has a field called type of activity (of the inspected facility). So, we are unable to present sectoral distribution of inspections and fines incidence for the entire database. Instead, we focus on plant specific regulatory activities as discussed in the summary statistics section 3D.

Sociodemographic data

We consider two indicators of socioeconomic and demographic characteristics that are based on Mexican census data conducted every ten years and the conteo data conducted every five years in between censuses. Marginalization index reported by Conapo is a measure of socioeconomic status of the local population. It is the first principal component of roughly 10 census variables that vary from one census (conteo) year to the next. They include education, health, housing conditions including sanitation. Scores range from small negative numbers to small positive numbers, with higher (more positive) index scores indicating greater marginalization. The second indicator we include is population density drawn from the same Conapo database but reported in the Mexico National Institute of Statistics and Geography's (INEGI for its Spanish acronym), Population and Housing Census.

These two variables are available at a dis-aggregate level of basic geostatistical census areas (AGEBs) that are fairly small urban areas with roughly 2000 inhabitants with homogeneous socioeconomic characteristics (). We calculate plant specific socioeconomic indicators by taking the average of AGEB level data that are within 1 km or 2km of each plant. We include lagged rather than contemporaneous values to avoid residential sorting in response to local conditions such as pollution. We assign census 2000 demographics to each facility's annual observations for 2004, 2005, 2006 and 2007; conteo 2005 demographics to each facility's annual observations from 2008, 2009, 2010 and 2011; and census 2010 demographics to each facility's annual observations from 2012, 2013, 2014 and 2015. So, given the disaggregate scale of our data, results hold for urban areas only across Mexico.

RETC data

The self-reported pollution database on toxic pollution is available from the environment ministry of Mexico (Secretaria de Medio Ambiente y Recursos Naturales, or Semarnat). The database which is essentially a pollutant release and transfers registry is updated annually with a couple of years' lag. It contains information on all polluters that are under federal jurisdiction and pollute into national waters. It covers eleven industrial sectors that are major toxic polluters defined as more than 1 kilogram of arsenic, cadmium, chromium, lead, mercury and nickel, emitted into air or discharged in water or land, annually (and more than 100 kilograms of cyanides). Since mandatory (self-)reporting began in June 2004, the sample of plants reporting positive amounts of toxic pollution varied remarkably from one year to the next. We access the database in 2017, with data until 2015. Based on the frequency of different pollutants and media reported, we focus on water pollution of the above seven toxic materials. We include both direct discharges and indirect into sewage as it is ultimately discharged into water without treatment or recycling ().

On average, the number of plants reporting water pollution for at least one of the seven toxic pollutants was around 700 facilities per year. But the panel was unbalanced exhibiting great variation over the years covered. Number of facilities reporting peaked at 1,153 facilities with water pollution reports in 2006 to only 242 facilities in 2014. Our sample is representative as the CEC (2011) reports statistics on 1,231 facilities in 2006 with water pollution discharges in Mexico. Accessing the complete RETC database for all media, we notice a switch from water to land for some facilities in the year 2010. Unfortunately, annual data on land pollution was concentrated between 2010 and 2015; while air pollution data reported was not sufficient to estimate panel data models.

We undertook manual consolidation of the annual databases to create a facility level panel. Each physical plant or business changed names, ownership, even sector and were assigned a new identity in the RETC database as the name of the establishment changed. The physical location of each plant had to be verified using geo-location tools. Most of these polluters belonged to the chemicals industry (close to 30% of the reports), followed by metal processing (13%) and automotive sectors. As expected, their locations were strictly correlated with big, urban areas. The distribution by states was: Estado de Mexico (18%), Tamaulipas (10%), Mexico City and Nuevo Leon (9%) and Jalisco (8%).

Summary Statistics

Our final sample size is 1,788 facilities reporting at least one of the seven toxic pollutants, over 2004-2015 and matched socioeconomic characteristics from the census data. On average, a plant got inspected at least 0.12 times annually (Table 1). Overall, a plant got fined much less frequently than it got inspected. On average, a plant faced a financial penalty 0.05 times in a year. On average, a plant in our sample faced fines of 169 USD in real terms, yearly. Table 1 also presents the relevant statistics for the variables used in the estimations namely past three years' inspections and fined indicators, and past three years' average fined amounts. Summary statistics for both 2 kilometers and 1 kilometer definitions of local community presented are close for the annual counts of inspections and fines with the actual fined amount being higher in the 1 kilometer definition due to smaller sample size.

Table 1 presents the summary statistics on the socioeconomic characteristics of the local community taken from the census years 2000, 2005 and 2010 and for both 2 kilometers and 1 kilometer definitions of local population around each plant. On average, marginalization index is higher for the 2 kilometers local areas (-0.84) than for the 1 kilometer areas (-0.91) i.e. broader urban areas around plants are more marginalized. As for population density, on average plants are located in denser areas for the 2 kilometers local areas (8.06) when compared to the 1 kilometer local areas (7.23). We infer that the 2 kilometer local areas are picking up denser urban areas that are also more marginalized within urban areas.

Last, we present the summary statistics of the seven toxic pollutants for the 2 kilometers and 1 kilometer local areas. The data are shown after preprocessing with 0.5% trimming. In the raw data, the maximum value for each of the seven pollutants was 40 to 80 standard deviations larger than the mean.[3] The bottom panel of Table 1 summarizes average toxic water pollution discharges across facilities. The number of observations varies across pollutants because not all facilities report emissions on each substance and for all the years. Among facilities reporting discharges and with socioeconomic and demographic data, mean discharges of Ni, Cr, Pb, Cd, CN-, As, and Hg are 40.67, 32.45, 28.77, 10.65, 6.63, 3.82, and 0.76 kilograms per year (for the 2 kilometers local areas). For all pollutants, discharges are highly variable and right skewed, especially Cr, Ni and Pb for both local area definitions of 2 and 1 kilometers.

EMPIRICAL STRATEGY

Our empirical strategy closely follows the conceptual economic model of Gray and Shadbegian (2004). Optimal environmental regulation is determined by both marginal costs and marginal benefits of pollution abatement. Marginal costs are dependent on plant characteristics like age, size, type of manufacturing facility while marginal benefits are dependent on location specific characteristics e.g. if communities are poorer or denser in terms of population then marginal benefits are higher due to either higher pollution levels or exposure to pollution levels. Optimal level of environmental regulation will be chosen when MB=MC. We adopt this conceptual model to the empirical questions that we address in this paper: 1) what factors determine inspections and fines by Profepa regulators and 2) whether increased regulatory

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[3] Main result point estimates are similar, but less precisely estimated, when using raw pollution data with no preprocessing.

pressure/activities exert any influence on environmental performance of Mexico's major toxic polluters.

Inspections Model

The hypothesis that we want to test is whether Profepa inspectors improve the self-reporting practices of the polluters subject to annual reporting. Inspections in Mexico do not validate self-reported levels by taking samples etc., neither does unusually high self-reported emissions trigger any inspections and enforcement actions based on its severity of violation. Rather enforcement actions such as monetary fines (partial or temporary closure of operation) are imposed when found in non-compliance with the procedures and record-keeping of these facilities. The only other paper on air emissions in Mexico City argues that even monetary fines imposed are not binding as the fined entities can appeal for either reduced sanctions or more time to come into compliance, in which case they might end up not paying any fine.

In an empirical framework, one might consider inspections frequency to be determined by Profepa budget, community pressure from the affected population, and normal targeting per guidelines to focus on high risk, toxics generating, or potential environment (health) impact on population. Equation (1) below presents the inspections model that is estimated using random effects probit model. We include a 0/1 indicator variable capturing whether the plant was fined at least once in the past 3 years. The fined indicator is meant to control for direct regulatory stringency that is targeted at the plant. We include an indicator of whether the plant was inspected at least once in the past 3 years. Profepa inspections often spilled over months and couple of years to finalize from initial visit through final administrative outcome like monetary fines (the only observable outcome in Profepa dataset). The past inspections indicator is a time varying plant specific variable that might not only capture plant specific targeting (other than type of manufacturing facility or size), at the same time it might proxy Profepa budgets. Ceteris paribus, higher inspections are predicted when resources to make annual visits are available.

We include lagged socioeconomic factors to control for indirect community pressure or higher regulatory pressure by inspectors based on vulnerability of the local population. We include marginalization index of the local population as it might capture reduced pressure on regulators to monitor and enforce proper emissions reporting protocol. Escobar and Chavez (2013) find that for their sample, inspectors conduct more activities in marginalized regions (using much broader municipality level data). We include population density as densely populated areas might capture increased concentration of industrial facilities in urban areas. The effect for regulatory activities, given budget, might imply fewer plants inspected or increased inspections based on exposure of local population.

Per the Profepa guidelines, manufacturing plants that are high risk (such as toxics generating) and/or large in size are targeted for regular inspections. We control for the type of manufacturing facility, e.g. chemicals (including petrochemicals), metallurgy, automobiles. Yearly controls are included to control for yearly changes such as Profepa budgets or government changes influencing inspections activity. State level dummy variables are included to control for time in-varying state specific factors variations in overall regulatory stringency differences in environmental attitudes leading to higher citizen complaints. Finally, we cluster standard errors within municipalities to control for arbitrary correlation across plants that are located in the same municipality.[4]

$$(1)\ Pr(Insp_{it}) = f(pastregulations, lagged\ socioeconomic, type, year, state)$$

We estimate the inspection model for each one of the seven pollutants separately as not all plants in our sample report all seven pollutants and for each year. Panel A of Table 2 present the results of the inspections model for the 2 kilometers and Panel B for the 1 kilometer local areas. The coefficients presented are the marginal effects calculated at mean values. In general, regulatory activities such as past inspections and fines in the past 3 years lead to higher inspections in the current year. The socioeconomic variables show that plants located in denser neighborhoods are

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[4] Clustering at the state level yield similar results.

subject to fewer inspections activities (while poorer neighborhoods also receive fewer inspections but rarely statistically significant).

Results in Panel A of Table 2 show that if a plant is fined at least once during the past 3 years, they are likely to receive more follow up inspections between 7 and 8 percentage points. For the 1 kilometer definition, the marginal effects are between 6 and 7 percentage points (Panel B). We interpret this result as effectiveness of the monitoring and enforcement mechanisms as non-compliance status is followed up with inspections visits (most likely to finalize the outcome of monetary fines). Similarly, if a plant is inspected at least once in the past 3 years, the probability that it receives a follow up inspection visit increases between 6 and 7 percentage points in Panel A and between 6 and 8 percentage points in Panel B. Again, this result points to the feedback mechanism of follow up of past inspections conducted in the past 3 years. An increase in population density on the other hand is associated with a lower probability of inspections between 0.5 and 0.6 percentage points when considering the 2 kilometer around each plant and between 0.2 and 0.3 percentage points when considering the 1 kilometer around each plant. The marginalization index is negative but not statistically significant. This is contrary to Escobar and Chavez's (2013) findings of increased inspection activities in poorer and denser municipalities and might be related to local factors such as a larger agglomeration of industries implying fewer regular visits of major polluting plants.

Fines Models

Equations (2) and (3) below present the model on monetary fines imposed on our sample of toxic polluters and the amount fined specifications. The fined 0/1 event model was estimated as a Random Effects Probit Model and the amount fined specification was estimated as a Tobit model censored at zero fines.

$$(2)\ Pr(Fine_{it}) = f(pastregulations, lagged\ socioeconomic, type, year, state)$$

$$(3)\ Fine_{it} = f(pastregulations, lagged\ socioeconomic, type, year, state)$$

Where, $Fine_{it} = \{0,1\}$ in equation (2) and $Fine_{it} \geq 0$ in equation (3)

Marginal effects calculated at mean values are presented in Table 3. Similar to the inspections models, a monetary fine imposed at least once in the past 3 years result in a higher probability of being fined in the current year by roughly 3 percentage points for both 2 kilometers and 1 kilometer definitions (Panels A and B). It might be worth pointing out that as discussed in the data section, amount fined often "carried over" to the next year or at times even two or three years when follow-up inspections were conducted to determine the final outcome i.e. the amount to be fined. In other words, we cannot interpret this result as targeting based on past violations as highlighted in Harrington and Helland. Similarly, a plant that is inspected at least once in the past 3 years result in a higher probability of being fined in the current year between 2 and 3 percentage points for the 2 kilometer areas (Panel A) and between 3 and 4 percentage points for the 1 kilometer areas (Panel B).

Overall, the lagged socioeconomic variables are less important for Profepa enforcement activities of imposing monetary fines or the amount fined. Higher population density results in lower probability of plants fined between 0.2 and 0.3 percentage points but only for the 2 kilometer areas. The coefficient on lagged marginalization index is negative in the 2 km models (similar to the monitoring results) but never statistically significant.

Table 4 presents the results of the amount fined models. Overall, the results are very similar to the dichotomous fined models with socioeconomic demographics rarely statistically significant other than higher population density leading to lower amounts fined for the 2 kilometer models. Higher past fines lead to higher fines in current year between 113 and 673 dollars (2010 USD) for the 2 kilometer areas in Panel A and between 101 and 677 dollars (2010 USD) for the 1 kilometer areas in Panel B. Higher inspections in the past three years lead to higher current fines between 159 and 486 dollars (2010 USD) for the 2 kilometer areas (Panel A, significant at higher values only) and between 195 and 613 dollars (2010 USD) for the 1 kilometer areas (Panel B of Table 4).

We infer that for finer definitions of local community like the 1 or 2 kilometers around each plant, Profepa regulators are unable to target facilities to address environmental justice concerns like conducting more inspections and enforcement in more marginalized communities. Having said that, environmental regulation (although limited in scope and function) were aptly followed up as past inspections that were either regular visits or visits that arose due to citizen complaints led to fines imposed on these plants as the final outcome of the follow-up verification visits.

Environmental Deterrence Models

In this section, we investigate whether regulatory stringency as captured by Profepa monitoring and enforcement activities have any environmental deterrence impact. This is the first analysis to match the self-reported toxics pollution data from plants (RETC) with the inspections, fines data for Mexico. Despite toxic waste being the predominant monitoring and enforcement program, no prior study has linked actual plant level emissions with monitoring and enforcement activities of major toxic polluters in Mexico. This question seems especially relevant as there is no parallel literature in Mexico on the regulatory mechanisms of inspections and enforcement for conventional pollutants under the Clean Water Act or the Clean Air Act like the U.S.

Exercising caution that the RETC is not a regulatory database rather a public disclosure mechanism, like the other toxic pollution registries in North America, we test the impact of monetary sanctions and inspections conducted on these plants on self-reported levels of toxics pollution. Our hypothesis is that plants that are mandated to self-report emissions in their annual Certificate-Of-Operation (COA for its Spanish acronym) report lower toxic pollution levels as a result of increased regulatory pressure like monetary fines imposed by the Profepa. Regarding inspection activities, we have no priors as high levels of self-reported emissions do not result in inspections and enforcement like the conventional pollutants. On the other hand, if learning-by-doing is significant when these inspectors review the self-reporting emissions records of the plants, then higher inspections might improve the self-reporting protocol and result in higher emissions reported. Evidence in other large developing countries like China also highlight the role of inspections in actually increasing the self-reported pollution levels (Lin, 2013).

Equation (4) below presents the panel data model of environmental pollution. Each of the seven toxic substances released into water is estimated separately. For facility *i* in year *t*, we regress logged pollution discharges on lagged number of inspections conducted by Profepa during the past three years, lagged total monetary fines imposed on the plant by Profepa inspectors during the past three years, lagged socioeconomic variables (marginalization index and population density) for the local area, plant and year fixed effects. The error term is clustered within municipalities to account for arbitrary correlations across facilities in the same municipality.[5] Keeping with the inspections and fines models, we estimate for both the 1km and 2km definitions of local community.

$$(4)\ ln(Pollution)_{it} = \alpha_i + \Phi S_{it} + \beta Lag\_Insp_{it} + \gamma Lag\_Fines_{it} + \rho_t Year_t + \varepsilon_{it}$$

Table 3 Panel A presents the within group panel analyses for the 2 kilometer definition of neighborhood and Panel B presents results from the 1 kilometer AGEB characteristics surrounding each plant. The coefficient on lagged fines in the past three years can be interpreted as higher fined amounts leading to reduction in pollution discharges of cyanides by 37% per year. Similarly, higher fines in the past three years result in a decline in nickel discharges by 31% per year, chromium discharges by 26% per year, and lead and cadmium discharges by 25% per year. For the definition of smaller neighborhoods, the coefficient on lagged fines is consistently negative (except arsenic discharges) with estimated coefficients very close to the results with 2km.

The coefficient on lagged number of inspections is positive in both the 2 kilometer and 1 kilometer local area definitions. An increase in number of inspections result in higher levels of self-reported emissions in the subsequent years, by 19% for cadmium discharges and 18% for cyanides discharges but rarely statistically significant at conventional levels. In the 1 kilometer models, the impact of past inspections is somewhat larger in magnitude for all seven pollutants, and at times statistically significant. Chromium discharges in the current year increase by 25% as a result of higher number of past inspections.

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[5] Upon clustering standard errors at the state-level, we get similar results.

Lagged marginalization index is positive meaning as communities become poorer pollution increase. The coefficient is significant mostly in the 1 kilometer local area definition. Interpreting the point estimates in Table 3 Panel B, while noting log-linear specifications and $\sigma_{marg.} = 1.24$, reveals that a 1 standard deviation increase in the marginalization index for the neighborhood around a facility results in: a 41.2% increase in lead discharges, 34.1% increase in nickel discharges, a 31.6% increase in cyanides discharges and 31.0% increase in chromium discharges. Lagged population density is positive and significant for all seven toxic pollutants. It might be capturing the scale effect of highly dense urban areas have higher industrial concentrations and higher pollution from the biggest plants.

DISCUSSION AND CONCLUSION

To our knowledge, this is the first comprehensive study on inspections and fines in Mexico and its impact on self-reported toxics pollution of major polluters nationwide. We find evidence on effectiveness of the inspections and fines process despite its limited role in verifying actual plant level emissions. Unlike developed countries, monitoring and enforcement in Mexico often spills over years and fines imposed are appealed strongly. However, our results show that the implementation of fines through verification visits are important in determining monitoring and enforcement at major polluters. In particular, past inspections and fines are followed up with higher inspections and fines in the current period. At least one more inspection visit in the past three years, leads to higher probability of visits in the current year by 6 percentage points for chromium polluters. At least one more fine imposed on the plant in the past three years, leads to higher probability of visits in the current year by 8 percentage points for chromium polluters. At least one more inspection during the past three years raise current fined probability by 2 percentage points (439 2010 dollars in monetary terms as seen in the tobit models) for chromium polluters. At least one more fine in past three years raise current fined probability by 3 percentage points (589 2010 dollars). Estimated marginal effects are very similar for the other toxics modeled. Local socioeconomic variables such as marginalization index are not significant in the regulatory models; while denser urban areas lower inspections and fines.

We find evidence of regulatory deterrence despite no explicit channels in place in terms of triggering regulatory activities if plants were self-reporting (abnormally) high levels of toxic pollution. Perhaps other incentives such as public image and citizen ire explain the deterrence effect of Profepa fines. A case in point is that Profepa is obligated to visit plants that are listed as citizen complaints rather than the regular monitoring programs. For the environmental deterrence models, past fines result in lower cyanides discharges by 37%, nickel discharges by 31%, chromium discharges by 26%, cadmium and lead discharges by 25% and mercury discharges by only 14%. Lagged inspections result in higher self-reported pollution levels in the current period. Estimated coefficients are greater in the 1 kilometer local area definitions, though rarely statistically significant. Increased number of inspections in the past three years, result in higher cyanides discharges by 22%, nickel discharges by 15%, chromium discharges by 25%, cadmium discharges by 23%, lead by only 4% and mercury by 11%.

For policy, our results imply that regulatory actions taken by the monitoring and enforcement agency in Mexico offset some of the environmental inequity aspects of higher pollution in denser and marginalized urban neighborhoods (Chakraborti and Shimshack). Despite fines not being levied based on high levels of self-reported toxic discharges, we find that past fines have the expected deterrence impact on plants by reducing their pollution levels in the current year. We interpret this finding as negative reputation effect of private manufacturing industries as facilities that fail to comply with emissions measurement and reporting protocol are perceived as laggards in corporate environmental responsibility, particularly in a dynamic globalizing economy like Mexico. Increased preferences for environment can be inferred from the exponential rise in the adoption of voluntary environmental certificates that required intensive personnel and management training around the same time period studied. Other literature point to the explanation of temporary monitoring relief for exponential rise in the number of manufacturing facilities enrolled. Lagged inspections on the other hand actually increase self-reported pollution levels. We interpret this result as evidence on learning-by-doing process of polluting facilities as they receive guidance from Profepa regulators on measurement and reporting protocols.

Appendix

Table 1. Summary Statistics of Regression Sample

	Obs.	Mean	Std. Dev.	Max.
Inspections				
Annual inspections (#), 2km	6,852	0.12	0.32	1.00
Annual inspections (#), 1km	6,226	0.12	0.32	1.00
Past 3-year indicator (0/1), 2km	6,852	0.23	0.42	1.00
Past 3-year indicator (0/1), 1km	6,226	0.22	0.41	1.00
Past 3-year inspections (#), 2km	6,852	0.30	0.61	3.00
Past 3-year inspections (#), 1km	6,226	0.29	0.61	3.00
Fines				
Annual fines (#), 2km	6,852	0.05	0.22	1.00
Annual fines (#), 1km	6,226	0.05	0.22	1.00
Annual fines (2010 USD), 2km	341	168.70	1499.74	22,789.46
Annual fines (2010 USD), 1km	311	181.80	1569.81	22,789.46
Past 3-year fined indicator, 2km	6,852	0.11	0.32	1.00
Past 3-year fined indicator, 1km	6,226	0.11	0.32	1.00
Past 3-year fines (2010 USD), 2km	777	173.56	1432.18	21,915.46
Past 3-year fines (2010 USD), 1km	701	186.22	1507.06	21,915.46
Socio-Demographics				
Marginalization Index, 2km	6,852	-0.84	1.18	5.04
Marginalization Index, 1km	6,226	-0.91	1.24	4.66
Population Density, 2km	6,852	8.06	5.34	26.72
Population Density, 1km	6,226	7.23	5.35	29.45

Pollution (kg)				
Arsenic (As), 2km	5,191	3.82	30.78	865.00
Arsenic (As), 1km	4,752	3.70	30.78	865.00
Cadmium (Cd), 2km	4,687	10.65	68.90	1,084.92
Cadmium (Cd), 1km	4,284	10.15	67.80	1,084.92
Chromium (Cr), 2km	4,861	32.45	245.26	4,418.82
Chromium (Cr), 1km	4,436	31.95	242.07	4,418.82
Cyanide (CN-), 2km	5,179	6.63	44.36	940.01
Cyanide (CN-), 1km	4,731	6.28	43.23	940.01
Lead (Pb), 2km	5,284	28.77	182.33	3,611.73
Lead (Pb), 1km	4,820	27.90	181.62	3,611.73
Mercury (Hg), 2km	4,919	0.76	6.54	147.32
Mercury (Hg), 1km	4,505	0.72	6.39	147.32
Nickel (Ni), 2km	5,369	40.67	228.96	4,213.29
Nickel (Ni), 1km	4,878	37.75	218.34	4,213.29

Table 2. Inspections Models

Panel A. RE Probit Inspections, Marginal effects at mean values, sociodemographic variables 2 kilometers							
Dep. Var. The log of:	As	Cd	Cr	CN-	Pb	Hg	Ni
Marginalization Index	-0.004 (0.005)	-0.002 (0.005)	-0.007 (0.005)	-0.006 (0.005)	-0.002 (0.005)	-0.005 (0.005)	-0.000 (0.005)
Population density	-0.005*** (0.002)	-0.006*** (0.002)	-0.006*** (0.002)	-0.005*** (0.002)	-0.005*** (0.002)	-0.006*** (0.002)	-0.005*** (0.002)

Past 3 yr. inspections (0/1)	0.068*** (0.013)	0.059*** (0.014)	0.055*** (0.014)	0.062*** (0.015)	0.071*** (0.014)	0.072*** (0.013)	0.055*** (0.013)
Past 3 yr. fines (0/1)	0.074*** (0.015)	0.081*** (0.016)	0.079*** (0.016)	0.067*** (0.015)	0.068*** (0.014)	0.070*** (0.017)	0.071*** (0.015)
Observations	5,191	4,649	4,826	5,129	5,242	4,876	5,369
Panel B. RE Probit Inspections, Marginal effects at mean values, sociodemographic variables 1 kilometer							
Dep. Var. The log of:	As	Cd	Cr	CN-	Pb	Hg	Ni
Marginalization Index	0.003 (0.005)	0.002 (0.006)	0.002 (0.006)	0.001 (0.005)	0.001 (0.005)	0.002 (0.005)	0.005 (0.005)
Population density	-0.002 (0.001)	-0.003** (0.002)	-0.003** (0.001)	-0.002 (0.001)	-0.003* (0.001)	-0.002 (0.002)	-0.003* (0.001)
Past 3 yr. inspections (0/1)	0.070*** (0.013)	0.064*** (0.013)	0.063*** (0.014)	0.068*** (0.013)	0.076*** (0.013)	0.077*** (0.013)	0.056*** (0.013)
Past 3 yr. fines (0/1)	0.066*** (0.015)	0.074*** (0.016)	0.071*** (0.016)	0.056*** (0.016)	0.062*** (0.014)	0.062*** (0.017)	0.068*** (0.015)
Observations	4,752	4,247	4,404	4,684	4,783	4,466	4,878

Notes: Standard errors clustered at municipality level in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 3. Fined Models

Panel A. RE Probit Fined, Marginal effects at mean values, sociodemographic variables 2 kilometers

Dep. Var. The log of:	As	Cd	Cr	CN-	Pb	Hg	Ni
Marginalization Index	-0.001 (0.003)	-0.001 (0.004)	-0.000 (0.003)	-0.002 (0.003)	-0.000 (0.003)	-0.002 (0.003)	0.001 (0.003)
Population density	-0.002* (0.001)	-0.003** (0.001)	-0.002** (0.001)	-0.002** (0.001)	-0.002** (0.001)	-0.003** (0.001)	-0.002 (0.001)
Past 3 yr. inspections (0/1)	0.028*** (0.006)	0.021*** (0.007)	0.023*** (0.007)	0.026*** (0.007)	0.028*** (0.006)	0.029*** (0.007)	0.021*** (0.006)
Past 3 yr. fines (0/1)	0.034*** (0.011)	0.038*** (0.010)	0.031*** (0.010)	0.032*** (0.010)	0.030*** (0.010)	0.035*** (0.012)	0.032*** (0.012)
Observations	5,001	4,595	4,774	5,101	5,189	4,838	5,256

Panel B. RE Probit Fined, Marginal effects at mean values, sociodemographic variables 1kilometer

Dep. Var: The log of:	As	Cd	Cr	CN-	Pb	Hg	Ni
Marginalization Index	0.001 (0.003)	0.001 (0.003)	0.002 (0.003)	0.000 (0.003)	0.001 (0.011)	0.001 (0.003)	0.002 (0.003)
Population density	0.000 (0.001)	-0.000 (0.001)	-0.000 (0.001)	-0.000 (0.001)	-0.001 (0.014)	-0.000 (0.001)	-0.000 (0.001)
Past 3 yr. inspections (0/1)	0.034*** (0.007)	0.027*** (0.008)	0.028*** (0.007)	0.033*** (0.007)	0.033 (1.388)	0.037*** (0.008)	0.026*** (0.007)

Past 3 yr. fines (0/1)	0.029** (0.012)	0.035*** (0.011)	0.029** (0.011)	0.029** (0.011)	0.029 (1.212)	0.029** (0.013)	0.033** (0.013)
Observations	4,593	4,201	4,359	4,637	4,737	4,414	4,781

Notes: Standard errors clustered at municipality level in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 4. Amount Fined Models

Panel A. Tobit Amount Fined, Marginal effects at mean values, sociodemographic variables 2 kilometers							
Dep. Var. The log of:	As	Cd	Cr	CN-	Pb	Hg	Ni
Marginalization Index	-74.24 (72.95)	-18.93 (23.21)	-75.39 (90.37)	-94.45 (80.45)	-16.55 (19.79)	-22.22 (20.33)	-23.84 (92.04)
Population density	-36.05 (28.96)	-10.81* (5.667)	-41.30 (32.24)	-41.71 (32.84)	-9.782* (5.319)	-9.067* (5.435)	-42.31 (32.33)
Past 3 yr. inspections (0/1)	485.9** (237.6)	159.1 (109.1)	438.5** (222.5)	452.3** (227.6)	187.7 (115.1)	183.6 (114.6)	484.3** (206.7)
Past 3 yr. fines (0/1)	532.6* (319.1)	148.6*** (54.50)	589.1* (347.3)	518.1* (312.8)	113.0** (44.48)	122.7*** (44.78)	673.2** (334.3)
Observations	5,191	4,687	4,861	5,179	5,284	4,919	5,369
Panel B. Tobit Amount Fined, Marginal effects at mean values, sociodemographic variables 1 kilometer							
Dep. Var. The log of:	As	Cd	Cr	CN-	Pb	Hg	Ni
Marginalization Index	-14.30 (55.97)	-9.590 (21.11)	-21.34 (68.99)	-27.44 (55.43)	-13.63 (18.98)	-15.85 (19.24)	17.29 (87.03)

Population density	-1.152 (16.82)	0.277 (5.127)	-14.10 (21.62)	-8.429 (20.20)	-1.028 (4.416)	1.991 (4.936)	-13.69 (23.25)
Past 3 yr. inspections (0/1)	613.0** (290.5)	195.3 (123.0)	545.1** (265.2)	585.2** (280.8)	215.9* (126.6)	226.5* (132.2)	567.9** (234.2)
Past 3 yr. fines (0/1)	470.3 (312.9)	133.3** (57.56)	550.0 (349.7)	457.3 (304.2)	102.4** (48.30)	100.6** (47.98)	676.9* (362.3)
Observations	4,752	4,284	4,436	4,731	4,820	4,505	4,878

Notes: Standard errors clustered at municipality level in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 5. Environmental Deterrence, Panel Data Models

Panel A. Panel regressions, facility by year data, sociodemographic variables 2 kilometers

Dep. Var. The log of:	As	Cd	Cr	CN-	Pb	Hg	Ni
Past 3 yr. lagged inspections	0.085 (0.140)	0.191 (0.152)	0.148 (0.137)	0.183 (0.134)	-0.027 (0.121)	0.063 (0.152)	0.082 (0.117)
Past 3 yr. lagged fines	0.013 (0.014)	-0.249 (0.165)	-0.257* (0.142)	-0.373*** (0.127)	-0.247 (0.152)	-0.142 (0.182)	-0.307*** (0.118)
Marginalization Index	-0.057 (0.121)	0.165 (0.149)	0.190 (0.131)	0.162 (0.121)	0.101 (0.123)	0.157 (0.135)	0.217* (0.126)
Population density	0.063 (0.102)	0.259*** (0.081)	0.223** (0.091)	0.248*** (0.094)	0.229** (0.095)	0.143 (0.100)	0.228*** (0.070)
R^2	0.02	0.05	0.05	0.02	0.04	0.01	0.05
Observations	5,191	4,687	4,861	5,179	5,284	4,919	5,369

Panel B. Panel regressions, facility by year data, sociodemographic variables 1kilometer							
Dep. Var. The log of:	As	Cd	Cr	CN-	Pb	Hg	Ni
Past 3 yr. lagged inspections	0.146 (0.146)	0.226 (0.152)	0.251* (0.136)	0.220 (0.136)	0.041 (0.127)	0.114 (0.160)	0.153 (0.118)
Past 3 yr. lagged fines	0.015 (0.013)	-0.246 (0.163)	-0.258* (0.140)	-0.371*** (0.125)	-0.245 (0.150)	-0.135 (0.178)	-0.308*** (0.116)
Marginalization Index	0.127 (0.128)	0.203 (0.145)	0.250* (0.131)	0.255* (0.130)	0.163 (0.140)	0.332** (0.145)	0.275** (0.139)
Population density	0.216* (0.114)	0.270*** (0.092)	0.212** (0.098)	0.232** (0.111)	0.267*** (0.082)	0.125 (0.124)	0.238*** (0.080)
R^2	0.02	0.06	0.06	0.02	0.05	0.02	0.06
Observations	4,752	4,284	4,436	4,731	4,820	4,505	4,878

Notes: Standard errors clustered at municipality level in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

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