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Informal or Formal Regulation: What Works for Toxics Emitting Industries in Mexico?

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Abstract

In this paper, we study whether formal regulatory pressure as opposed to informal community pressure are predominant factors in determining environmental compliance. Our sample of 2 889 major toxics releasing industries in Mexico, over a period of 2004 to 2012, is the most comprehensive database linking environmental performance as measured by self-reported toxics discharged into water, with a measure of socio-economic status and inspections and sanctions implemented by regulatory agencies. To our surprise, we find that only fines imposed have a deterring effect on pollution; while, past inspections increase current pollution levels. This is in contrast to most regulatory impacts studied in developed countries such as the US. Lack of monitoring and enforcement resources likely means that inspectors are unable to frequently visit major polluters, and sampling inspections are the exception rather than the norm. On the other hand, our conclusion on the informal regulation component is in contrast to previous studies on Mexico, but similar to findings from developed nations. We find that an increase in the marginalization index by one unit leads to an increase in chromium emissions by 69%, one more person per sq. km leads to a decline in chromium emissions by 13%; one more inspection leads to an increase in arsenic emissions by 63%, one more fine imposed results in a decline in arsenic emissions by 68%. The relative importance however varies depending on the toxic substance under consideration.

Keywords: Environmental Justice, Specific Deterrence, Toxics, Environmental Compliance, Mexico

Resumen

En este documento de trabajo estudiamos las consecuencias de la presión regulatoria formal en contraste con la presión informal de comunidades como factores predominantes para determinar el cumplimiento de normas ambientales. Nuestra muestra abarca 2 889 industrias, las cuales son importantes respecto a la emisión de toxinas en México en un período de 2004 a 2012. Esta base de datos es la más completa al relacionar el desempeño ambiental medido por los tóxicos autoreportados vertidos en el agua, con una medida de estatus socioeconómico e inspecciones y sanciones implementados por las agencias reguladoras. Para nuestra sorpresa, encontramos que sólo las multas impuestas tienen un efecto disuasivo sobre la contaminación; mientras que las inspecciones anteriores aumentan los niveles actuales de contaminación. Esto se contrasta con la mayoría de los impactos regulatorios estudiados en países desarrollados como los EE. UU. La falta de recursos impide el monitoreo y aplicación de normas y consecuentemente los inspectores, con frecuencia, no pueden monitorear ni dar seguimiento a las industrias más contaminantes y las inspecciones con muestreo son la excepción más que la norma. Nuestra conclusión sobre el componente de regulación informal contrasta con estudios previos sobre México, pero es similar a los hallazgos de países desarrollados. Encontramos que un aumento en el índice de marginación en una unidad conduce a un aumento en las emisiones de cromo en un 69%, una persona más por kilómetro cuadrado conduce a una disminución de las emisiones de cromo en un 13%; una inspección más lleva a un aumento en las emisiones de arsénico en un 63%, una multa impuesta tiene como resultado una disminución en las emisiones de arsénico en un 68%. Sin embargo, la importancia relativa varía según la sustancia tóxica considerada.

Palabras clave*:* Justicia ambiental, Disuasión específica, Sustancias tóxicas, Cumplimiento ambiental, México

Introduction

IIn developing countries, where formal regulatory mechanisms such as inspections and enforcement are often weak, informal community pressure can be the principal pollution control mechanism. It seems especially likely in such cases that richer, more educated communities will persuade neighboring industrial plants to undertake more pollution abatement. Efficacy of pollution control mechanisms for a prominent, rapidly developing economy like Mexico, takes front stage in terms of its policy relevance. This paper will investigate whether formal and/or informal regulatory channels are significant determinants of environmental toxic pollution, for major polluters in Mexico.

Previous studies have looked at this question of environmental regulation in Mexico, but only on a piecemeal basis and using very specific survey data and/or data that are limited in scope. Here, we look at frequent toxic emissions into water for seven important pollutants (that are known to have environmental health burden on neighboring communities). The only prior evidence that we find, based on which we frame our hypothesis, is that environmental authorities might be redressing this disproportionate impact of exposure to environmental pollution. However, it is for conventional air emissions and in Mexico City, only. Escobar and Chavez (2013) find that greater regulatory efforts are directed towards larger industries (and hence more polluting) as well as in poorer and dense neighborhoods. Second, we evaluate whether the distribution of the burden of pollution falls disproportionately on the urban poor. The only evidence on community pressure is from a dated survey in 1995 (Dasgupta, Hettige and Wheeler, 2000). The authors find that plants which report greater indirect community pressure (as opposed to formal regulatory pressure) do not exhibit greater environmental effort than their counterparts. Lastly, Blackman and Guerrero (2012) is the only study to incorporate a comprehensive database on regulatory fines (as a proxy for environmental performance); however, their research question is different—the role of voluntary certification as a mechanism for environmental regulation. Hence, no previous study has undertaken upon itself to answer whether formal regulatory factors such as inspections and enforcement activities have a significant influence on toxics releases of firms.

We create a novel database linking the environmental performance of plants (measured as emissions into water) with inspections and enforcements and sanctions imposed on firms. We have a panel of close to 3000 manufacturing facilities, from 2004 to 2012, that self-report annual toxics emissions mandated by the Environmental Law in Mexico. We collect data on monitoring and enforcement by the regulatory agency in Mexico that conducts inspections at major manufacturing plants, for the entire time period overlapping with plant level emissions, as well as sanctions and fines imposed on these firms. Lastly, we gather data on proxies for community pressure so called informal regulation by spatially matching these industries with a local (urban) marginalization index (IMU for its Spanish acronym) published by the Mexican government. Admittedly, reverse causality problem in pollution and income relationship is unavoidable; hence, we choose instruments for income and poverty like the marginalization index that captures the lower end of the income distribution. It is calculated based on indicators of education, social status indicators like houses without drainage, piped water, mud floor, refrigerator, overcrowding, and septic connection, and demographic indicators like child mortality rate of women between 15 and 49 years of age and population without access to health services. In addition, we include population density as higher exposure might capture increased willingness to engage in collective action and hence the community pressure channel.

Our preliminary results show that both informal and formal regulatory variables are important indicators of pollution control, in Mexico. However, the coefficients on the community characteristics variables seem to be stronger and of the expected sign (negative on density and positive on marginalization index) across the different specifications. Formal inspections and sanctions (such as fines) against a specific industry do not always have the expected deterrence effect (negative sign); while, the deterrence effect of inspections and sanctions on other plants (in the same sector and state) are weaker in absolute terms, compared to density and IMU. Overall, there is a pattern that for well known (to the average citizens) toxics like arsenic the formal regulatory activities are more significant than the less well known toxics like chromium (for the latter, pollution is higher in less dense and more marginalized communities).

DATA

Self-Reported Toxics (RETC) database

The emissions data originate in a 2001 amendment to Mexico's General Law of Ecological Equilibrium and Environmental Protection (*Ley General de Equilibrio Ecológico y Protección al Ambiente*) and a rulemaking process over the subsequent years. As of June 2004, virtually all entities that make use of more than small amounts of toxic substances (104 are listed) need to report how much of each substance ends up where (i.e., discharged into land, water or air, or sent to recycling facilities). More precisely, the requirement applies to any facility that handles hazardous waste or discharges pollutants into national water bodies, and to any firm in the 11 industrial sectors responsible for most pollution, if either its total use or total discharge exceeds a threshold established for each substance.[1]

The Mexican Secretariat for the Environment and Natural Resources *(Secretaria de Medio Ambiente y Recursos Naturales,* or Semarnat) compiles data from these reports into the Pollutant Release and Transfer Register (*Registro de Emisiones y*

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[1] These sectors are: petroleum, chemicals, paints and ink manufacturing, primary and fabricated metals, automotive, pulp and paper, cement/limestone, asbestos, glass, electric utilities, and hazardous waste management.

Transferencias de Contaminantes, or RETC) which has been available to the public online since 2006. With a couple of years´ lag, the data is also archived by the Commission for Environmental Cooperation of North America (CEC), an intergovernmental agency established in a side accord with the North American Free Trade Agreement in 1994.

> The size of the RETC database nearly doubled in its first decade, from 1,714 establishments in 2004 to 3,529 in 2013 (Semarnat 2013). This probably represents a failure to elicit compliance in the early years, as there was nothing close to a doubling in the size of the covered industries. It seems likely that the later cross sections are more representative. In addition to the inherent implausibility of so many new establishments coming into being, this judgment is suggested by other expert opinion. For example, the Commission for Environmental Cooperation of North America (CEC), an intergovernmental agency established in a side accord with the 1994 North American Free Trade Agreement, judges it likely that many plants had not yet installed pollution measurement equipment or trained personnel in the early years (CEC 2014).
>
> Our decision to study discharges into water was originally guided by a belief that the affected population is more reliably people nearby than is the case for air or land emissions. These data also appear to be more complete than other aspects of these reports. (In contrast to water, most of the land emissions data are from after 2010.) We are currently working on incorporating the land emissions data in our main model as it is not uncommon to consider aggregate emissions of toxics as an alternative model.
>
> Our project covers seven pollutants that are fairly common (among the top 25 pollutants for on-site water releases, in Mexico[2]) and pose some of the greatest threats to health from exposure (CEC 2009): Arsenic, cadmium, chromium, lead, mercury, and nickel, together with their compounds, and cyanide (organic and inorganic). Except for cyanide, firms are required to report on these if the total amount manufactured, processed, or otherwise used exceeds 5 kg per year, or the amount emitted exceeds 1 kg. For cyanide, the thresholds are 2500 kg used or 100 kg emitted. Most of the annual pollution reports are actually below the emissions thresholds. According to the CEC (2014), most of these facilities report their releases because the production threshold is binding. Facilities use a variety of methods to measure or estimate their emissions, including emission factors, mass balance, engineering calculation, stack testing and direct measurement. When reporting under their annual operation certificates (*Cedula de Operacion*, COA), facilities include information about the type of method used. To date, we were unable to ascertain this information related to the database, except that when industries are inspected, the protocol includes verifying whether certified lab services were used for measurement of its emissions.
>
> We have reason to suspect substantial inaccuracy in these reports. For this reason, we are not making use of the full annual frequency of data. Instead, we

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[2] http://www.cec.org/Page.asp?PageID=749&SiteNodeID=1215&BL_ExpandID=754

> work with the following three-year averages--2004 to 2006, 2007 to 2009 and 2010 to 2012 (see Table 1). Again, this is reflected in the views of other experts. Simple reporting errors appear to be common. According to a Semarnat official, these include "errors in the conversion of units and errors in the selection of the appropriate substance for report (substances with similar names are often interchanged)" (Eicker *et al*. 2010, pp. 11-12). In addition, information on method used to report annual pollution levels is not publicly available. On top of this, we have found some cases of very improbable consistency: About a quarter of the pollution reports have duplicates at the same plant out to five or six significant digits, either for other metals or other years. Much of this plausibly corresponds to the precision of monitoring devices, but there are cases (such as 161.8841 kg of lead for the years 2010 and 2011) which can hardly be interpreted as anything other than failure to take new measurements.

The RETC database had to be cleaned up substantially before we could get meaningful measures of pollution reported. Each industry or business establishment includes an identifier (NRA code), name, address and geographic location. However, the same physical plant or business can have multiple NRA codes if it has multiple activities e.g. generation of electricity and treatment of toxic residuals; and each time the business changes name, ownership change, sector designation, headquarters address, etc. it gets a new NRA code. Hence, we had to manually consolidate the number of 'unique' RETC facilities (i.e. same physical plant/business) with the multiple NRA codes across the different years in the database. Second, beyond our preliminary analysis, we take on the cumbersome task of verifying the physical location of these plants. Subsequently, we georeferenced each and every polluter with water emissions data in our RETC sample (2,889 manufacturing plants). We used Mexico´s Statistical Agency´s (INEGI´s) National Directory and Statistics on Economic Units (DENUE) database and mapping software to validate the location of each polluter. From the DENUE directory, we obtained plant specific information like number of employees.

Table 1. Average Water Emissions 2004-2012

Variable	Obs.	Mean	Standard deviation	Min	Max
Arsenic, 2004-2006	1,149	.016791	.2617701	5.63e-16	8.21
Arsenic, 2007-2009	999	.0188142	.2608377	8.17e-20	6.996607
Arsenic, 2010-2012	401	.009928	.1250368	3.00e-13	2.487045
Cadmium, 2004-2006	1,026	.0126355	.1029118	2.00e-13	2.487
Cadmium, 2007-2009	967	.2303159	4.888461	7.57e-20	147.1176
Cadmium, 2010-2012	414	.0265318	.1663457	1.00e-13	2.665539
Chromium, 2004-2006	1,022	.0662068	.7196515	1.37e-12	12.492
Chromium, 2007-2009	952	.3127599	5.158148	2.00e-18	114.075
Chromium, 2010-2012	419	.2737909	2.317875	2.10e-12	31.31504
Cyanide, 2004-2006	1,152	.0149644	.1798555	5.63e-16	4.151649
Cyanide, 2007-2009	1,027	.0787197	1.011343	7.57e-20	19.42197
Cyanide, 2010-2012	400	.0667387	1.065388	8.00e-12	21.28291
Lead, 2004-2006	1,102	.0451888	.4886841	2.80e-12	13.2
Lead, 2007-2009	1,043	21.69124	694.2207	3.00e-18	22420.12
Lead, 2010-2012	445	.102115	1.009893	2.00e-12	20.47721
Mercury, 2004-2006	1,125	.0144271	.284915	1.00e-13	8.21
Mercury, 2007-2009	983	.8846827	27.50354	1.51e-20	862.3125
Mercury, 2010-2012	390	.0011534	.0069287	1.00e-13	.0872159
Nickel, 2004-2006	1,090	.0519128	.3703564	2.50e-12	7.848
Nickel, 2007-2009	1,024	33.63557	1059.936	9.00e-18	33917.63
Nickel, 2010-2012	478	.1228921	.7442872	4.00e-12	10.25455

Note: All pollution data are in kilograms.

Enforcement and Deterrence in Mexico

We obtain inspections and fines data for all industries and businesses in Mexico, from 2000 to present. Profepa (*Procuraduría Federal de Protección al Ambiente*) is the agency in charge of enforcement and inspections of all industries subject to environmental regulation (LGEEPA) in Mexico. From communications with Profepa officials, and the only one previous study on inspections and sanctions in Mexico, monitoring and enforcement activities are conducted by state level regulators (under federal oversight and supervision). Typically, federal Profepas target industries in high risk activities including major emitters of toxic residuals into air, water and land. Larger plants are also targeted because these are more likely to generate greater volumes of toxic residuals. In the recent years, the agency publishes a summary report on its monitoring and enforcement activities for the entire country (Profepa 2016).

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 he or she judges 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 judgement. All the evidence collected in 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 this resolution several months can pass. The fines are calculated on the basis of the final resolution. From the data that we obtained, to date, we were unable to verify whether plants were closed permanently as a final outcome of the enforcement actions.

Mexico´s industrial geography is distinct with large clusters in and around the capital city and other big metropolitan cities. However, increasingly the focus has shifted from the *maquiladoras* in the northern border cities to the South in general. And more recently in states surrounding the capital such as Tlaxcala, Queretaro and Puebla as well as some poorer, less diverse regions further in the South such as Tamaulipas, Tabasco and Veracruz. Based on availability of resources and concerns of population density exposed to industrial pollution, it is widely expected that there is substantial variability in stringency of regulator ´presence´, across regions and within states. This paper seeks to find empirical evidence on the impact of inspections and sanctions such as fines on industrial pollution reported. The empirical framework relies heavily on enforcement and compliance literature of (mostly) US air and water pollution regulations.

Inspections Data

We examine inspections and fines data from 2000 to 2012 because the self-reported industrial pollution database is obtained from 2004 to 2012. State inspectors conduct inspections and impose fines based on violations under different programs. These are mainly eight or nine industrial activities including emissions into air, land and water. Toxic waste or residual is the largest inspections program (without classifying the medium into which it is disposed of). About, 53% of the visits. High risk activities (11% of all visits), biological residuals (9%) and environmental impact (about 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. So, after the initial visits, there are verification visits after which firms are obligated by law to take measures to get back into compliance status or sanctions typically fines are followed as resolution to administrative actions of enforcement. Between 2000 and 2012, Profepa conducted 85,888 visits of which 56% were regular inspection activities, 32% were follow up verification visits, about 8% citizen complaints and the remaining 3% emergencies. On average, Profepa conducted about 7000 annual visits not differentiating between regular inspections and verification and complaints. Across the years, this distribution of types of visits did not change much as seen in the graph.

Next, we explore heterogeneity across states. As expected, the highest frequency of visits was in metropolitan cities and states with large industrial clusters. Visits to industries in the Mexico City Metropolitan Area (MCMA) comprised 10% of all visits during the period examined, close to 5% of all visits were for industries located in Baja California, Chihuahua and Coahuila (north, border regions), Estado de Mexico (north of the capital), Puebla and Tlaxcala (south and east of capital), Nuevo Leon (with Monterrey), and Tamaulipas in the South. 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%.

On average, industries in the chemical (10%) and petroleum and petrochemicals (about 9%) sector was inspected the most (other than the sector classification of “Others” which includes mostly services and sales associated with the manufacturing activities). Metallurgy (8%), health services (8%), food (7%), and toxic waste treatment (5%) are among the other major sectors inspected. It is not immediately clear, whether this pattern follows the Profepa guidelines of monitoring highly risky and toxic waste generating industries. On average, a plant got inspected at least once annually.

Sanctions and Fines Data

On average, a plant got fined much less frequently than it got inspected. On average, a plant in the database faced a financial penalty 0.4 times in a year. The fines data exhibit considerable variability in terms of pecuniary sanctions both across years and industrial sectors; 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. Here we focus on fines greater than 10,000 $ in any year. In 2004, the number of plants fined significant penalties spiked at 14 and beyond 2006 there are no plants fined in that amount (except for a toxics treatment plant in 2008 fined for 21,084.85 dollars). Drinks (including alcohol) and tobacco industries followed by chemicals (including petrochemical) and automobiles sector were heavily fined. We notice that the June 2004 mandatory reporting on toxics pollution might have an impact on improving environmental performance as the frequency of plants that were inspected and fined heavily reduced after 2005.

Specific and General Deterrence Measures

In order to get 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 (with self-reported toxics emissions information). Based on industry names, address 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. Presumably, that is if we were to take both databases at face value, in particular the inspections database, the remaining plants with toxics reports were not inspected and/or fined by the Profepa regulators.

The enforcement and deterrence literature is well established in the US. Regulatory interventions such as inspections and enforcement activities have been shown to improve environmental performance in Magat and Viscusi (1990), Deily and Gray (1991), Gray and Deily (1996); and more recently in Earnhart (2004a), Shimshack and Ward (2005), Glicksman and Earnhart (2007) and Shimshack and Ward (2008). Most of these papers deal with conventional (water) pollutants such as biological-oxygen-demand (BOD) and total suspended solids (TSS). Mostly because the Toxics Releases Inventory (TRI) in the US serves as a (mandatory) public information disclosure mechanism rather than being regulated by traditional programs like the Clean Water Act (CWA) and the Clean Air Act (CAA). Among Latin American countries, we could find only one study in Uruguay (Caffera and Lagomarsino, 2014) that investigated effectiveness of formal regulatory measures for BOD.

We heavily rely on this literature to come up with our specific and general deterrence measures. These are: number of inspections and fines imposed against a particular plant in our sample, in a year. We also calculate the monetary fines imposed against each plant in a year. For general deterrence, we calculate the number of inspections and fines imposed against similar plants in the same state, in a year. The Profepa database did not contain any systematic categorization of the industries that were inspected and fined. We manually assigned the broad "sector" classification (total of 22 sectors) based on "activity" recorded in the inspection database for each industry. Some of the industries undertook activities that fell under multiple sectors—

e.g. chemicals and plastics. We generated these general deterrence measures for both types of classifications (our results are similar).

Lastly, since our annual toxics emitted reports suffer from apparent inconsistencies and lack of variability (as mentioned before in the pollution reports discussion), we generate specific and general deterrence measures as averages for each three-year period examined 2004 to 2006, 2007 to 2009 and 2010 to 2012. We consider average inspections and fines imposed in the previous time period or three years as current inspections (and enforcement) are endogenous to the pollution reporting model. For example, a large industry in the chemical sector might be targeted by Profepa for inspections annually and/or higher fines if found in violation (based on the volume and environmental impact of toxics emitted by this plant).

Table 2 below presents the summary statistics of the specific and general deterrence variables used in the regressions. For the plants in our sample, on average a plant faced 0.3 inspection visits against itself during the past three-year period and 0.1 fines imposed on itself during the past three years. During the past three years, a plant on average faced 7.6 inspection visits on others (in the same sector) and state and 2 fines imposed on others in same state.

Table 2. Summary Statistics of Log Pollution, Community Features, and Deterrence

Variable	Obs.	Mean	Standard deviation	Min	Max
log average emissions, 2004-2012					
Arsenic	2,549	-4.438713	4.67115	-37.04348	9.013108
Cadmium	2,407	-2.878855	4.490628	-37.11975	11.89899
Chromium	2,393	-2.111892	4.577402	-33.84563	11.64461
Cyanide	2,579	-3.115801	4.532345	-37.11975	9.965659
Lead	2,590	-1.418046	4.340801	-33.44016	16.92547
Mercury	2,498	-5.521639	4.446666	-38.73184	13.66737
Nickel	2,592	-1.095036	4.413131	-32.34155	17.33945
Community Characteristics					
Marginalization Index, 1990	2,546	-1.579451	.5709393	-2.678	.92
Population Density, 2000-2010	6,364	43.62014	39.35214	.0015818	275.9271
Specific and General Deterrence					
Lagged Inspections, past 3 years	6,644	.3171282	.8875348	0	16
Lagged Sanctions, past 3 years	6,644	.1401264	.4611249	0	6
Lagged Inspections on others, same state	6,644	7.622517	31.34073	0	596
Lagged Sanctions on others, same state	6,644	2.040939	11.65322	0	307
Plant Size					
Range of employees, 2010	1,766	2.156852	.8744248	1	3

Informal Regulation and Local Community Characteristics

Informal regulation or local community pressure have been shown to improve compliance in developing countries (where formal enforcement is weak) as well as in developed countries. Since community pressure cannot be observed directly most of the times, studies look at proxies such as socio-economic characteristics of the population affected. Most of the empirical literature stemmed from Hamilton's (1995) classification of discrimination based on gender, economic vulnerability, and willingness to engage in collective action. The predicted correlation has been found in many studies of the United States (Brooks and Sethi (1997) on air emissions; Arora and Cason (1998) on aggregate emissions; Helland and Whitford (2003) on emissions into air, water, and land treated separately), although not in all (Gray *et al*. 2012). On water emissions, community characteristics such as income per capita and non-white percentage have been shown to improve compliance in Earnhart (2004b) and Bandyopadhyay and Horowitz (2006). Viscusi and Hamilton's (1999) find that Superfund sites near politically active communities get more ambitious clean-up targets. Similarly, Gray and Shadbegian (2004) find that plants in areas with politically active populations that are also environmentally conscious emit less pollution.

In developing world, early evidence comes from Indonesia (Pargal and Wheeler 1996). However, the evidence is much more mixed from Latin American countries such as higher pollution associated with higher wage, urban municipalities in Brazil (Dasgupta, Lucas and Wheeler, 2002) and from a 1995 confidential survey of 236 major polluters in Mexico found only about a fourth consider pressure from the neighboring community a significant factor in environmental decisions (Dasgupta, Hettige and Wheeler, 2000). Also in Mexico, Blackman, Batz, and Evans (2004) report that in Ciudad Juarez the export-assembly plants known as *maquiladoras* contribute substantially to air pollution, but it does not seem the poor are disproportionately affected.

When looking for proxies for community pressure one must be careful about the reverse causality problem. For example, the community characteristics are themselves influenced by higher pollution levels hence one needs to be careful in their choice of community pressure indicators. At the very least, the local community characteristics need to be from a year prior to the pollution report years (Arora and Cason 1998).

Mexico’s Census of Population and Housing did not directly ask questions on the income or poverty status of households. In Chakraborti and Margolis (2017), we present preliminary evidence that toxics discharges into water are indeed higher in more marginalized communities, across the country. We use the Urban Marginalization Index (IMU) that is published by the Mexican Government’s National Population Council (*Consejo Nacional de Población*, Conapo). It is calculated based on the census data and the *Conteo* (count data) years.[3] It is available in Conapo´s website

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[3] The *Conteo* databases are actually censuses that collect information on a smaller number of household characteristics compared to the Census databases.

from 1990 onwards, but at the level of municipalities for the first census year reported (reporting at a more disaggregate level of AGEBs (*Área Geoestadística Básica Urbana*) began in 2000).[4] In addition, we cannot use the calculations from different years, in a panel framework as the underlying variables used to construct this index changed from one year to the next; not to mention that they cannot be compared temporally as they are scaled against the corresponding variables in each year. The index measure aspects of education, housing and health diagnostic of poverty, but not income per se, which is largely unavailable in Mexican census data, and considered very unreliable among the poor even when measured. IMU is the first principal component of the underlying socioeconomic variables. The indices generated are categorized into five classes of "very high", "high", "medium", "low" and "very low", with positive numbers classified as highly marginalized and negative numbers as low marginalized.

In this paper, we extend the analysis by incorporating IMU indices from the earliest year available (Census 1990). Going back in time, minimizes the reverse causality effect of richer people moving out of more polluted areas; since our objective is to isolate the first causal impact of industries increasing pollution in areas with higher marginalization index.

We include population density as a measure of local community characteristics as this variable might explain plant behavior e.g. denser neighborhoods are exposed to greater pollution burden (per person) and hence might exert more pressure independently of their socioeconomic status as captured by the marginalization index. We used census data from all three years (Census 2000, Count 2005 and Census 2010) that were closest to our period of analysis (2004-2012). That is, we assign population density calculated using 2000 census to emissions data from 2004-2006, 2005 count data to emissions data from 2007-2009, and 2010 census data to emissions from 2010-2012. For each plant in our sample, we assign a measure of population density based on underlying data from AGEBs that were in one kilometer radius. About a third

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[4] AGEBs are roughly comparable to urban census tracts in the United States. AGEBs are fairly small urban areas with more than 2,500 inhabitants and relatively homogeneous socioeconomic characteristics.

of the plants were not a kilometer of any AGEBs Presumably, these were cases of AGEBs with very low populations. Hence, we interpret our results as characterizing *urban* emissions sources. We have examined population density data using two and five kilometers as well (Tables 4 and 5); we notice a decline in magnitude (and significance) with the five-kilometer data that show much weaker correlations with emissions, while the two-kilometer data is very much like the one-kilometer radius.

Other Plant Specific Data and Controls

Our model incorporates a plant specific measure of size as captured by number of employees. It is a plant specific (time-invariant) variable and we know how it should influence emissions i.e. larger plants are expected to pollute more. We gather this information from DENUE 2010 database. Each industry or business reports a range for its number of employees: 0 to 5, 6 to 10, 11 to 30, 31 to 50, 51 to 100, 101 to 250 or over 250 persons employed. We construct our size measure by categorizing all industries in three classes: small (0 to 100), medium (101 to 250) and large (over 250). The respective proportions were: 32 % small plants, 21% medium plants and 47% large plants.

Ideally we would have plant fixed effects (or dummies) that control for everything else other than our measure of socioeconomic categorization that explains emissions levels. But we cannot include plant fixed effects not only because of small sample size for each toxic substance regressions, but also because it would drop our time-invariant marginalization index (from the same year Census 1990) which is assigned to all three time periods.

Location specific effects as captured by state level dummies that control for state level variations in environmental regulations stringency, among other factors such as political attitudes.

EMPIRICAL MODEL

> In a typical enforcement model a plant chooses that level of pollution abatement at which the marginal benefits of lower pollution abatement are equal to its expected costs of non-compliance (with the regulation). The underlying economic

> framework is a cost minimization problem which is a function of its pollution abatement, production (factors such as type of manufacturing facility and size of operation etc). Hence, a plant's choice of pollution abatement is a function of its expected costs of non-compliance which in turn is a function of the probability of being found in violation and the expected penalties of violation. So, in a reduced form framework a plant´s level of pollution abatement depends on formal regulatory pressure (inspections and sanctions and fines) and informal regulation or community pressure either directly by influencing regulators through environmental complaints against industries or indirectly through news media and environmental organizations (reputation effect).
>
> Our main models make use of pollution levels averaged across three year periods for the nine years of pollution data available; which we hope will reduce the impact of some of the data problems mentioned above. We do, however, disaggregate on one important dimension. In all the models, each substance is treated separately, since it is likely their health impacts differ (although the Semarnat threshold choice, indicate aggregation of the metals is not wholly meaningless).

Equation (1) below presents the pooled OLS estimation where our dependent variable is the pooled three-year average toxic emissions of each substance. We exploit the panel nature of our toxics reports data by running a pooled OLS model but including IMU measure from only one year (e.g. 1990 or 2000) in order to pool the pollution averages data from the three time periods of three years:2004 to 2006, 2007 to 2009 and 2010 to 2012. As mentioned before the IMU indices are not comparable over time. In addition, we estimate equation (1) based on IMU constructed using alternative radii of 2 km and 5 km in order to check consistency of our estimated coefficients.

$$lPoll_{ist} = \alpha + \beta size_i + \gamma IMU_{it_0} + \delta popden_{it} + \theta_i state_i + \mu_t period_t + \varepsilon_{ist} \qquad (1)$$

> Where t refers to the three time periods of 2004 to 2006, 2007 to 2009 and 2010 to 2012, $lPoll_{ist}$ is the log of average toxic emission of substance s, by plant$i$ and in time period t, and IMU_{it_0} is the "Urban Marginalization Index" (the principal component constructed from ten to eleven underlying socioeconomic variables selected by CONAPO). The yeart_0 refers to the earliest census year with available data, 1990. The idea here is to establish that the relationship that we identify between current pollution and marginalization index before the years' pollution reporting became mandatory is not sensitive to our choice of census year from which this community characterization is drawn. This choice also reflects a nod towards suggestive causal interpretation: we think of the IMU as chiefly a cause (as it is a proxy for poverty), and this interpretation is stronger if the IMU is always from an earlier date.

Our estimation controls for other factors that influence a plant's environmental performance. The variable $size_i$ refers to the time-invariant proxy for plant size as captured by number of employees. The variable $popden_{it}$is the population density of the surrounding AGEBs (within 1 km) calculated from the 2000 and 2010 censuses and 2005 count data. Similar to our marginalization index, we utilize census and count data from years prior to when pollution reporting became mandatory, in order to minimize problems of reverse causality of current pollution influencing demographic characteristics of the nearby population. [5] Emissions data from 2004-2006 was regressed on population density data from the 2000 census, for example, that from 2007-2009 on the 2005 count data, and that from 2010-2012 on 2010 census data.

Finally, we cluster standard errors within each plant as we expect pollution levels from the same plant to be correlated over time.

RESULTS

Overall, we find that both formal and informal regulation measures exert an influence in plant level toxic emissions into water. Tables 3, 4 and 5 present the pooled OLS results with alternative radii for the population density measure. Our measure of community pressure is available at the scale of municipalities which are larger areas than AGEBs. More marginalized communities face higher pollution levels, as seen in the positive coefficients on IMU1990. Formal regulation as captured by the specific and general deterrence measures seem to exert a more strategic response on the part of polluters. Admittedly, unlike the literature, we have not adequately instrumented for current inspections and enforcement (by estimating an inspections and/or enforcement model), we speculate that our empirical specification suffers less from endogenous inspections and fines problem, as we consider three-year average regressions rather than an annual frequency. On average, higher inspections against a specific plant in the past three years seem to encourage strategic behavior as plants actually increase their emissions level in the current time period. Industries might be

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[5] Utilizing population density calculated from 1990, 1995 and 2000 censuses and count, for regressions of average pollution from 2004 to 2006, 2007 to 2009 and 2010 to 2012, respectively, yielded very similar coefficients.

acting strategically as limited resources for the regulators mean that Profepa is unable to inspect each major industry, every year, especially if the plant is not found in violation (Harrington 1988 and Helland 1998 on regulatory targeting). Sanctions, in particular, imposition of fines against a specific plant seem to have the expected deterrence effect of reducing emissions levels in the subsequent period. However, the coefficient is rarely statistically significant. On average, higher lagged inspections on plants in the same sector and state seem to have the expected general deterrence effect of lower emissions in the current time period. However, this result is often not statistically significant and depends on the toxic substance considered. Below, we discuss the specific coefficients across the three tables.

The coefficient on the marginalization index (from 1990) can be interpreted as a one-unit increase in IMU, above the average community, results in an increase in chromium emissions by 69% (column (3) of Table 3). Table 4 presents the results with population density calculated using a 2 km radius. Higher marginalization is again associated with an increase in emissions (as one would expect if more marginalized communities exert less community pressure to reduce exposure to pollution). The coefficient in column (3) can be interpreted as an increase in IMU by one unit, above the average community, leads to an increase in chromium emissions by 60%. Finally, for the 5 km radius, an increase in IMU leads to an increase in chromium emissions by 60% (column (3) of Table 5). Since, the marginalization index are calculated at the level of municipalities, we do not see the decline in magnitude of this coefficient when considering wider radii for the population density variable. The coefficient is not always statistically significant and depends on the toxic substance in particular chromium, cyanide and mercury.

We include population density as a community variable that might also capture local community pressure. Denser population implies population exposed to a given amount of toxic emissions are higher and hence higher the incentive of local community to engage in collective action such as protests and formal complaints. As expected, higher population density is a strong indicator of local pressure and exerts a negative impact on toxic emissions. The coefficient in Table 3 (for the 1km radius) can be interpreted as an increase in density by one person per square kilometer from the average community leads to a decline in chromium emissions by 13%. For more diffuse definitions of local community, the magnitude declines somewhat but not substantially (12% and 9% for the 2 and 5 km radii respectively). Overall, across the toxics considered, there seems to be a decline in magnitude (and statistical significance) especially when considering the broader 5 km radius.

Next, we interpret the formal regulatory measures. In Table 3, one more inspection visit in the past three years' period, against a specific plant, leads to an increase in arsenic emissions by 63% (column (1)). The coefficient remains around that magnitude when considering alternative radii for the AGEB variable. Column (1) in Tables 4 and 5, one more inspection against a specific plant in the prior time period, leads to an increase in arsenic emissions by 70 and 69% respectively. The sign is not what we expect to see on a specific deterrence measure as we infer that polluters might be engaging in strategic emissions behavior in lieu of scarce monitoring and enforcement resources. Overall, the positive coefficient is statistically significant (always) for arsenic, cyanide, lead and mercury.

We find the expected negative coefficient on the specific deterrence measure for sanctions, in particular, fines imposed against a plant in the previous three-year period. The coefficient however is rarely statically significant. In column (1) of Tables 3, 4 and 5, one more fine action imposed on a specific plant in the previous time period results in a decline in arsenic emissions by 68, 79 and 81% respectively.

Both the measures of general deterrence seem to have the expected negative coefficient; though it is rarely statistically significant. The coefficient in Table 3 column (1) can be interpreted as one more inspection visit against other plants in the same sector and state leads to a decline in arsenic emissions in subsequent time period by 1.4%. The magnitude remains comparable when considering alternative community radii (1.4% and 1.1% respectively). In absolute terms, the magnitude of the general deterrence is much smaller than the specific deterrence measures (as expected). However, the sign on general deterrence for lagged fines on other plants in the same sector and state, is not consistent as we move across toxic substances and/or community definitions.

Lastly, our measure of plant size as captured by a time-invariant record on number of employees (from the most recent year 2010 available) has the expected positive coefficient across all the three tables. The coefficient in column (1) of Table 3 can be interpreted as an increase in number of employees by one more unit (our proxy for plant size and scale of operation) leads to higher arsenic emissions by over 100 percent. Our controls for type of industry and other state specific differences and time period controls are in general significant in explaining current emissions levels.

Overall, we notice to some extent a complementary role of formal and informal regulatory measures—toxics like chromium has strong informal regulation effects but weak formal regulatory effects; while, toxics like arsenic has strong formal regulatory effects but weak informal community effects. To a certain extent this difference might be explained by substances that are well established and well known by average citizens, like arsenic and lead, they might engage in formal citizen complaints against such emissions whereas the ones that are well known mostly in the scientific community and not the average citizen might see stronger informal or lack of community pressure effects (well known in the environmental justice literature) such as more marginalized communities witness higher chromium emissions.

CONCLUSIONS AND FUTURE WORK

We build the most comprehensive database linking multiple sources the Semarnat with toxics reports, the Profepa in charge of making inspection visits and imposing sanctions and administrative measures of compliance to major industries in Mexico. Lastly, we look for informal community measures that answers whether more marginalized communities face higher pollution burden (Conapo´s IMU index). We have a lot of remaining areas to polish this preliminary paper. Overall, this data assimilation process has been extremely time consuming and manually intensive as there is no correspondence as we move across the various datasets (in particular there is disconnect between pollution reports and monitoring and enforcement databases). We used extensive georeferencing and geographic software for the informal regulation component. Below I highlight some of the future work.

We need to investigate the inspections and fines data more carefully, in particular obtain more information on what types of inspections are usually conducted by the Profepa regulators and the different types of temporary and final outcomes (including fines and closures that might result). Formal inspections and enforcement models might yield a better clue to evidence on effectiveness of formal regulatory pressures in Mexico.

Similar to Chakraborti and Margolis (2017), we plan on relaxing the log-linearity assumption of our main pollution model. For example, look at ordered logit estimations by breaking the pollution levels into several bins and examine marginal effects of our main explanatory variables within each category. This is because the pollution data spans a very great range, from micrograms to kilograms. At the lower end, a pollution increase of, say, 300% is a change from one innocuous level to another; at the upper end it is immense. Thus we do not wish to treat the same log-difference as the same amount in these two cases.

Land emissions data will be added to make the third and last panel more complete, after georeferencing these plants, especially because the regulation facing these industries are the same as emissions into water and we observe a switch from water to land for some of the plants, in our sample (Chakraborti *et al*. 2016).

References

Arora, S. and T. N. Cason (1998). Do community characteristics influence environmental outcomes? *Journal of Applied Economics, I* (2), 413-453.

Blackman, A., M. Batz, and D. Evans (2004). Maquiladoras, air pollution, and human health in Ciudad Juárez and El Paso. RFF Discussion Paper, 3–18, Resources for the Future, Washington, DC.

Blackman, Allen & Guerrero, Santiago, 2012. "What drives voluntary eco-certification in Mexico?" Journal of Comparative Economics, Elsevier, vol. 40(2), pages 256-268.

Brooks, N. and R. Sethi (1997). The distribution of pollution: Community characteristics and exposure to air toxics. *Journal of Environmental Economics and Management, 32*(2), 233-250.

Caffera, Marcelo and Alejandro Lagomarsino, 2014 "Under reporting of water pollution by industrial plants: empirical evidence" Latin American and Caribbean Environmental Economics Program LACEEP Working Paper Series, WP66.

Chakraborti, Lopamudra & Michael Margolis, 2017. "Do industries pollute more in poorer neighborhoods? Evidence from toxic releasing plants in Mexico," *Economics Bulletin*, AccessEcon, vol. 37(2), pages 853-870.

Chakraborti, Lopamudra, Michael Margolis & José Jaime Sainz Santamaria, 2016. "Do industires pollute more in poorer neighborhoods? Evidence from toxic releasing plants in Mexico," *Working papers* DTE 597, *CIDE, División de Economía*.

Commission for Environmental Cooperation. (2009). *Taking Stock: 2005 North American Pollutant Releases and Transfers*. Montreal, Canada: Commission for Environmental Cooperation.

Commission for Environmental Cooperation (CEC) (2014). *Taking Stock: North American Pollutant Releases and Transfers*. Vol. 14. Montreal, Canada.

Dasgupta, S., H. Hettige, and D. Wheeler (2000). What improves environmental compliance? Evidence from Mexican industry. *Journal of Environmental Economics and Management, 39*(1), 39-66.

Dasgupta, S., R .Lucas, and D. Wheeler (2002). Plant size, industrial air pollution, and local incomes: Evidence from Mexico and Brazil. *Environment and Development Economics 7*(2), 365-381.

Deily, M. and W. Gray (1991), "Enforcement of pollution regulations in a declining industry", *Journal of Environmental Economics and Management* 21(3):260-274.

Earnhart, D. (2004a), "Regulatory factors shaping environmental performance at publicly-owned treatment plants", *Journal of Environmental Economics and Management* 48(1):655-681.

Earnhart, D. (2004b), "The Effects of Community Characteristics on Polluter Compliance Levels", *Land Economics* 80(3):408-432.

Eicker, M., T. Ruddy, R. Zah, and H. Hurni (2010). Potentials of Latin American pollutant release and transfer registers as a source of local data for environmental assessments. Paper presented at the Annual Meeting of the International Association for Impact Assessment (IAIA), Geneva, Switzerland.

Escobar, N. and C. Chavez (2013), "Monitoring, Firms' Compliance, and Imposition of Fines: Evidence from the Federal Industrial Inspection Program in Mexico City," *Environment and Development Economics* 18(6):723-748.

Glicksman, R. and D. Earnhart (2007), "The Comparative Effectiveness of GovernmentInterventions on Environmental Performance in the Chemical Industry", *Stanford*

Environmental Law Journal 26(2):317-371.

Gray, W.B. and M. Deily (1996), "Compliance and enforcement: Air pollution regulation in the U.S. steel industry", *Journal of Environmental Economics and Management* 31(1):96-111.

Gray, W. and R. J. Shadbegian (2004). Optimal pollution abatement – whose benefits matter and how much? *Journal of Environmental Economics and Management*, *47*, 510-534.

Gray, W. B., R. J. Shadbegian, and A. Wolverton (2012). Environmental justice: Do poor and minority populations face more hazards? *Oxford Handbook of the Economics of Poverty.* Philip N. Jefferson (Ed.). Oxford University Press.

Hamilton, J. (1995). Testing for environmental racism: prejudice, profits, political power? *Journal of Policy Analysis and Management, 14*(1),107-132.

Harrington, W. 1988. "Enforcement leverage when penalties are restricted." *J. Public Econ.* 37(1),29–53.

Helland, E.,1998. "The enforcement of pollution control laws: inspections, violations, and self-reporting." *Rev.Econ.Stat.*80(1),141–153.

Helland, E. and A. B. Whitford (2003). Pollution incidence and political jurisdiction: Evidence from the TRI. *Journal of Environmental Economics and Management, 46*(3), 403-424.

Magat, W.A. and W. K. Viscusi (1990), "Effectiveness of the EPA's Regulatory Enforcement: The Case of Industrial Effluent Standards", *Journal of Law and Economics* 33(2):331-360.

Pargal, Sheoli and David Wheeler, 1996. "Informal Regulation of Industrial Pollution in Developing Countries: Evidence from Indonesia" *Journal of Political Economy*, 1996, vol. 104, issue 6, pages 1314-27.

PROFEPA. 2016. *Informe Anual de Actividades 2016*. *Procuraduría Federal de Protección al Ambiente*. Retrieved from https://www.gob.mx/cms/uploads/attachment/file/196266/Informe_de_actividades_2016.pdf.

SEMARNAT. (2013). RETC, *Registro de Emisiones y Transferencias de Contaminantes.* Retrieved from http://app1.semarnat.gob.mx/retc/retc/PresentacionRETC2013.pdf.

Shimshack, J. P. and M. B.Ward (2008), "Enforcement and over-compliance", *Journal of Environmental Economics and Management* 55(1):90-105.

Shimshack, J. P. and M.B. Ward (2005), "Regulator reputation, enforcement, and environmental compliance*", Journal of Environmental Economics and Management 50(3):519-540.*

Viscusi, W. and J. Hamilton (1999). Are risk regulators rational? Evidence from hazardous waste cleanup decisions. *American Economic Review, 89*, 1010-1027.

Table 3. Log Emissions 2004-2012 on Marginalization Index (IMU) from 1990, Lagged Specific and General Deterrence, Density from AGEBS 1km

	(1) Arsenic	(2) Cadmium	(3) Chromium	(4) Cyanide	(5) Lead	(6) Mercury	(7) Nickel
plant size	1.140***	1.021***	1.145***	1.054***	1.172***	1.110***	1.239***
	(0.142)	(0.148)	(0.152)	(0.139)	(0.138)	(0.140)	(0.137)
density	-0.010***	-0.013***	-0.013***	-0.011***	-0.009**	-0.009**	-0.011***
	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)
IMU1990	0.235	0.225	0.685**	0.465*	0.319	0.504**	0.341
	(0.260)	(0.263)	(0.277)	(0.250)	(0.250)	(0.250)	(0.249)
lagged inspections	0.625***	0.283	0.157	0.523**	0.404*	0.480**	0.334
	(0.224)	(0.260)	(0.266)	(0.208)	(0.239)	(0.219)	(0.234)
lagged sanctions	-0.679*	-0.139	-0.000	-0.468	-0.490	-0.616	-0.224
	(0.405)	(0.426)	(0.455)	(0.399)	(0.401)	(0.443)	(0.411)
lagged inspections,	-0.014***	-0.005	-0.003	-0.008	-0.005	-0.009*	-0.006
on others	(0.005)	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
lagged sanctions,	0.027**	0.007	-0.007	0.004	0.004	0.018	0.003
on others	(0.013)	(0.015)	(0.010)	(0.011)	(0.011)	(0.011)	(0.011)
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Period Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.19	0.14	0.19	0.17	0.15	0.16	0.15
N	1,840	1,745	1,744	1,852	1,882	1,807	1,899

Note: Standard errors in parentheses; * p<0.1; ** p<0.05; *** p<0.01.

Table 4. Log Emissions 2004-2012 on Marginalization Index (IMU) from 1990, Lagged Specific and General Deterrence, Density from AGEBs 2km

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Arsenic	**Cadmium**	**Chromium**	**Cyanide**	**Lead**	**Mercury**	**Nickel**
plant size	1.119***	1.031***	1.139***	1.098***	1.164***	1.119***	1.241***
	(0.141)	(0.144)	(0.146)	(0.135)	(0.132)	(0.136)	(0.132)
density	-0.006*	-0.010***	-0.012***	-0.008**	-0.006	-0.004	-0.007**
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
IMU1990	0.331	0.227	0.598**	0.503**	0.359	0.591**	0.398
	(0.263)	(0.261)	(0.265)	(0.235)	(0.238)	(0.246)	(0.242)
lagged inspections	0.705***	0.396	0.198	0.645***	0.463**	0.593***	0.399*
	(0.212)	(0.248)	(0.250)	(0.195)	(0.227)	(0.220)	(0.224)
lagged sanctions	-0.791**	-0.324	-0.132	-0.640	-0.612	-0.730*	-0.332
	(0.395)	(0.418)	(0.441)	(0.390)	(0.393)	(0.441)	(0.399)
lagged inspections, on others	-0.014***	-0.006	-0.003	-0.009*	-0.005	-0.009**	-0.007
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
lagged sanctions, on others	0.027*	0.008	-0.006	0.005	0.006	0.017	0.005
	(0.014)	(0.015)	(0.010)	(0.011)	(0.010)	(0.011)	(0.011)
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Period Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.19	0.13	0.19	0.18	0.15	0.16	0.15
N	1,960	1,861	1,851	1,974	2,001	1,923	2,018

Note: Standard errors in parentheses; * p<0.1; ** p<0.05; *** p<0.01.

Table 5. Log Emissions 2004-2012 on Marginalization Index (IMU) from 1990, Lagged Specific and General Deterrence, Density from AGEBs 5km

	(1) **Arsenic**	**(2)** **Cadmium**	**(3)** **Chromium**	**(4)** **Cyanide**	**(5)** **Lead**	**(6)** **Mercury**	**(7)** **Nickel**
plant size	1.135***	1.055***	1.179***	1.070***	1.187***	1.139***	1.288***
	(0.136)	(0.140)	(0.142)	(0.130)	(0.129)	(0.132)	(0.128)
density	-0.008*	-0.010**	-0.009**	-0.006	-0.006	-0.006	-0.004
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
IMU1990	0.353	0.308	0.609**	0.501**	0.358	0.513**	0.477*
	(0.260)	(0.269)	(0.270)	(0.245)	(0.241)	(0.252)	(0.243)
lagged inspections	0.685***	0.342	0.224	0.695***	0.387*	0.602***	0.321
	(0.204)	(0.241)	(0.240)	(0.201)	(0.222)	(0.210)	(0.224)
lagged sanctions	-0.811**	-0.309	-0.183	-0.763*	-0.593	-0.808*	-0.309
	(0.390)	(0.416)	(0.431)	(0.389)	(0.389)	(0.434)	(0.398)
lagged inspections,	-0.011***	-0.001	-0.002	-0.007	-0.002	-0.009*	-0.003
on others	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
lagged sanctions,	0.018	-0.001	-0.008	0.002	0.001	0.015	-0.001
on others	(0.012)	(0.015)	(0.010)	(0.012)	(0.011)	(0.012)	(0.011)
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Period Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.18	0.13	0.18	0.17	0.15	0.16	0.15
N	2,083	1,985	1,968	2,098	2,130	2,045	2,141

Note: Standard errors in parentheses; * p<0.1; ** p<0.05; *** p<0.01.