Regulator Reputation Effects in Developing Countries: Evidence from the Toxics Pollution Registry of Mexico

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ABSTRACT: In this study, we document regulator reputation effects in a developing country. We construct a panel on 3,432 major toxic polluters from 2004 to 2015 using detailed plant-specific data on pollution, inspections, and fines. Results show that: regulators target polluters based on past violations; fines induce more accurate self-reporting and result in higher self-reported pollution at the sanctioned facility; increased fines on other polluters lead to long-term improvements in environmental performance and reductions in toxic pollution. An increase in amount fined by 1% on all others in the same municipality leads to an individual plant reducing its annual pollution discharges by 0.1% for all seven toxics examined. These findings are significant as toxic pollutants are harmful even at small concentrations. We highlight synergies in costs of monitoring and enforcement of mandatory reporting regulation.

Keywords: Environmental Deterrence; Inspections and Fines; developing countries; Toxics Pollution Registry; Regulator Regulation Effects; Voluntary Environmental Regulation

JEL CODES: K32, Q52, Q53, Q58

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1. INTRODUCTION

Cost effective environmental regulation is relevant for developing countries, where budgets for environmental protection are typically small. One particular concern is monitoring and enforcement. On the one hand, any regulation of environmental pollution such as air, water (surface and groundwater), and land cannot be effective without appropriate monitoring and enforcement of these regulations. On the other hand, monitoring and enforcement actions are costly. Evidence suggests a significant portion of the costs of implementing environmental laws arises from the costs incurred by the regulatory agencies from inspections, enforcement actions, and judicial actions on polluters found in non-compliance (Gray and Shimshack 2011).

In this paper, we study the impact of monitoring and enforcement activities on the behavior of major toxic polluters in Mexico. One of the main contributions of this paper is that we find evidence that regulatory pressure channels that exist in developed countries also operate in developing country settings. We find that despite only a few fines imposed on individual polluters, there exists a significant deterrence impact on toxic pollutant discharges due to regulator reputation effects (Shimshack and Ward 2005). Policymakers need to consider these spill-over effects as it implies significant cost-efficiency of these rarely imposed monetary fines.

To explore our questions, we create a comprehensive panel data on 3,432 major toxics generating facilities from 2004 to 2015 by matching annual pollution reports on seven toxics with the inspections and fines data of the federal regulatory agency. We estimate panel data models for inspections, fines, fined amounts, and toxic pollution levels. To address idiosyncratic targeting, we include regulatory activities under other (non-toxic) programs as higher toxic water pollution discharge of the plant may not influence monitoring and enforcement actions under other inspection programs. The only other study that looks at determinants of monitoring and fines is

Escobar and Chavez (2013) for conventional air emissions in Mexico City. However, they do not consider actual emissions reported by major polluters. Past evidence on voluntary environmental initiatives is that environmental certificates are limited to short-term improvements in environmental performance. Hence, the effectiveness of regulatory activities like inspections and enforcement actions such as monetary fines remains an open question.

We find three main results. First, we find evidence that inspections and fines decisions are consistent with the compliance history of the individual facility. Results show that if a plant has one more violation under the toxic program in the past, the probability that it receives an inspection visit increases by around one percentage point for all seven toxics. We find that if a plant has one more violation under all other programs in the past, the probability that it receives an inspection visit increases by 1-2 percentage points for all seven toxics. One more inspection visit on others in the past results in a higher probability of being inspected by 0.1 percentage points for all seven toxics. Past violations for toxic inspections raise the probability of monetary fines by 3-4 percentage points and the amount fined by 1%. We find that one more inspection visit on others in the past on all other facilities in the same municipality results in a higher probability of being fined by less than 0.1 percentage point (statistically significant for all seven toxics). Higher toxic inspections on others in the same municipality leads to a higher fined amount by 0.1%.

Second, we show that regulator fines on others in the same jurisdiction leads polluters to reduce their plant's toxic pollutant discharges.[2] For the pollution models, we find strong evidence on general regulator reputation effects. Results show that a 1% increase in amount fined on other facilities in the same municipality results in decline in annual cadmium, chromium, cyanide, and lead discharges by 0.05-0.10%. For the remaining three toxic pollutants (arsenic, mercury, and

[2] Blackman (2012) show that plants that faced fines were more likely to adopt voluntary environmental management practices to avoid the burden of inspections and sanctions of regulators.

nickel), the coefficient on lagged fined amount on others is consistently negative but not always significant at conventional levels (0.01-0.06%). Magnitudes are small, but toxic substances are damaging even at tiny concentrations (CEC, 2018). The other noteworthy finding in the pollution models is that one more priority violation under the toxic program leads to an increase in annual cadmium, cyanide, and nickel discharges by around 0.2%. Results show that one more priority violation under other programs also leads plants to increase annual cadmium, chromium, cyanide, lead, and nickel discharges by 0.4-0.6%. This result is not surprising as plants are likely to be inspected under toxic and other programs simultaneously.

Third, we find that despite concerns of widespread regulatory capture, a status of significant non-compliance for the plant itself increases pollution levels reported. We infer that regulatory pressure directed at individual polluters are effective in improving pollution reporting and measurement protocols. Put differently, we provide novel evidence that formal regulatory actions such as inspections and fines imposed are on polluters with recent violations. We find that significant non-compliance results in plants updating their pollution reports improving the accuracy of pollution records. We find strong evidence that higher fines on facilities in the same municipality result in a general deterrence impact. We infer that in the absence of enforceable limits on plant-specific pollution reporting, concern for a bad public image due to considerable media attention when fined provides the incentive to reduce pollution levels.[3] Saha and Mohr

[3] Perla, M. (2018, February 18), Profepa multa a KIA Motors por más de 7 mill 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 14), Multa Profepa con 3.7 milliones 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 4), *La Verdad*. Retrieved from: https://laverdadnoticias.com/ecologia/PROFEPA-realiza-multas-en-Tabasco-por-casi-30-millones-de-pesos-20181204-0143.html.

(2013) find that media attention has a deterring effect on pollution from toxics releasing facilities in the U.S.

2. BACKGROUND MONITORING AND ENFORCEMENT

Monitoring and enforcement actions can be quite time-consuming and costly procedures for both developed and developing countries. Environmental inspections 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 depend on the severity of the violation and compliance history of the facility. Usually, they begin with administrative orders and might end in financial penalties and closure of the operation, following civil and criminal litigations. Regulators target polluters based on local marginal benefits and costs of monitoring and enforcement on those that are in non-compliance (Helland, 1998; Gray and Shadbegian, 2004). Inspectors target bigger, more polluting plants and plants belonging to the high human health risk and environmental impacts, such as chemical manufacturing. Regulators also target frequent violators that have a previous history of non-compliance (Shimshack 2014).

Regulatory interventions such as inspections and enforcement activities improve environmental performance in developed countries such as the U.S. For deterrence, both specific actions against the individual polluter as well as general regulatory actions against all other plants under the same legal jurisdiction improve compliance by reducing violations (Shimshack and Ward 2005) or improve over-compliance (Shimshack and Ward 2008). Shimshack and Ward (2005) highlight the mechanism that plants update their beliefs by observing regulatory actions like increased sanctions on all other plants in the same regulatory jurisdiction in the U.S. The authors also mention that the expected fines on the plant might underestimate the true economic costs of sanctions due to bad publicity or degraded reputation with the regulators.[4]

Recent evidence from large emerging economies suggests that weak institutions and limited budget result in environmental regulatory actions that are, to some extent, limited. Gupta et al. (2019) find evidence that large air and water-polluting plants in one state in India improved compliance when faced with more inspections and violation notices. Regulators targeted plants based on their compliance history and dirty industries but implement less stringent enforcement actions if they were more profitable or listed in stock exchange markets. Similarly, China's pollution levy system shows that inspections verify plants' self-reported pollution but does not improve performance by reducing their pollution (Lin, 2013).

In Latin America, Caffera and Lagomarsino (2014) find that polluters adjust conventional water pollution discharges upwards in the presence of municipal inspectors in Uruguay. Regarding deterrence, they report the limited effectiveness of specific deterrence in contrast to general deterrence measures such as increased plant closures. Fines on others that are less visible events did not have significant general deterrence impacts. In Colombia, Briceno and Chavez (2010) find that enforcement and control actions (like sampling inspections) taken by the local corporation of Corpochivor leads to lower self-reported levels of conventional water pollutants. However, enforcement and monitoring activities do not influence the final payment of the discharge fees.

Industrial pollution regulation in Mexico is still at its nascent stage. It implemented a two-fold approach; first, through command-and-control regulations based on mandatory reporting thresholds, and second through voluntary initiatives by manufacturers that invest in pollution abatement to comply with third-party environmental audits (Blackman, 2010). The focus of the

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[4] For a comprehensive review of the environmental deterrence literature focused on the US, see Gray and Shimshack (2011).

environmental law in Mexico is to ascertain that plants that are major polluters of toxic substances into the water regularly sample and measure emissions annually. Inspection visits to check on its emissions sampling and measurement records and imposing fines on those that failed to adhere to pollution measurement protocols are the mechanisms to promote regular measurement and reporting of pollution emissions. There are no limits on how much each plant can pollute. On the other hand, reporting abnormally high emissions compared to the entire industry or sector or even national scale results in these reports flagged as inconsistent and separated from the main emissions registry (personal communication, SEMARNAT, 2015).

Escobar and Chavez (2013) show that larger industries in Mexico City that are more polluting under the air emissions program face greater regulatory efforts. However, their analysis does not consider plant-specific pollution levels at all. Using a small sample of 34 manufacturing facilities under federal jurisdiction and inspections visits during 2011, Camacho (2016) reports that inspectors target larger plants (captured by the value of production), plants with higher environmental impacts, and high-risk sectors, e.g., the petrochemicals, chemicals, and metals processing.

There is no prior evidence on the impact of monitoring and enforcement in improving the environmental performance of major polluters or in increasing the accuracy of self-reported pollution emissions. Dasgupta et al. (2000) use survey data from 1995 from 236 major facilities in Mexico to provide one of the first evidence on self-assessed environmental compliance. Blackman et al. (2010) find that voluntary mechanisms such as obtaining Clean Industry Certificates have limited effectiveness in improving long-term environmental compliance. The authors point out that plants seek out audits to get these environmental certificates primarily to access the synergies of two years' inspection relief and a reputation of environmental stewards in

Mexican manufacturing. We interpret this evidence as polluters in Mexico largely operating under cost-minimizing principles and evidence of the burden of fines imposed (even though they are contestable in a court of law).

Community characteristics are significant determinants of compliance behavior for major polluters, even in developed country settings (Earnhart, 2004). On the other hand, community characteristics are generally not significant determinants of inspections and enforcement actions (Shimshack and Ward, 2005). Gray and Shadbegian (2004) include the environmental preferences of state-level constituents in the inspections and enforcement models and plant-level pollution models. In Santiago (Chile), Palacios and Chavez (2005) find that areas with higher population density have a lower probability of compliance, while areas with higher income witness higher compliance. Escobar and Chavez (2013) find greater inspection efforts in poorer and denser municipalities in Mexico. Recent evidence on plants polluting more in more marginalized communities across Mexico comes from Chakraborti and Shimshack (2020). The authors use detailed socioeconomic data to show that plant-level pollution increases by 15-40% as 1-kilometer areas surrounding each plant become more marginalized. For our present purposes, we utilize aggregate municipality level census data in the regulatory actions and pollution reporting models.

3. DATA

We obtain inspections and fines data for all industries and businesses in Mexico from 2000 onwards. To include variables on formal regulatory actions, such as inspections and fines, we had to manually match the plants in the annual inspections and fines database with the plants in the annual pollution database. Based on industry names, addresses, and other locational information, about a third of our plants with pollution reports faced any formal inspections and fines activities over the entire period. Hence, we assume that toxics reporting plants not appearing in the inspections and fines database did not face any inspections and fines by the regulators.[5]

3A. PROFEPA data

In June of 2004, Mexico adopted mandatory reporting of major toxics releasing plants under federal jurisdiction and discharging into the nation's waters. Major polluters are those that discharge more than a certain level of toxic pollutants. PROFEPA (*Procuraduría Federal de Protección al Ambiente*) is the agency responsible for inspections of all major facilities subject to Mexico's General Law of Ecological Equilibrium and Environmental Protection (*Ley General de Equilibrio Ecológico y Protección al Ambiente*, LGEEPA). Regulatory capacity is weak due to a lack of coordination between semiautonomous agencies like the PROFEPA and the Ministry of the Environment (SEMARNAT) (Challenger et al., 2018).

Unlike the monitoring protocol of environmental protection agencies in developed countries, inspection and enforcement in Mexico have a much more limited role. Rather than taking samples of actual emissions, inspections are "limited to surveillance of the aspects that are regulated [Alvarez-Larrauri and Fogel (2008), page 5]". Inspectors check the documentation on permits (whether they are current and payments made) and measurement records going back up to three years (whether samples were sent to accredited labs for measurement and recorded). State regulators conduct monitoring and enforcement activities under federal oversight and supervision (PROFEPA, 2016).

Inspection protocols for manufacturing facilities fall under six programs, e.g., high-risk activities, toxic waste management, environmental impact, land, air (fixed sources), and water

[5] In robustness checks, we estimate all the models, inspections, fines, amount fined, and pollution, including only the plants that appeared in both databases i.e. reported toxic discharges and faced regulatory actions at least once, over 2004 to 2015. Results are consistent in sign but much noisily estimated in the regulatory actions models.

pollution. Each plant is subject to specific regulations, depending on its activity. During the visit to the plant, the inspector checks the plant's records that support its compliance with all the environmental norms that apply. For water and other polluting activities, inspectors usually verify that an accredited lab has measured the discharges and permits are valid. For air emissions, inspectors also engage in visual inspection of equipment and perhaps operation (PROFEPA, 2013). The outcome of the visit can be either no irregularities, minor irregularities, urgent measures to take, priority attention, or temporary (partial or total) closure of operation. For the empirical models, we define significant non-compliance status as any of the last three outcomes mentioned above. The various actions under final resolution are the closure of administrative records with no measures required, agreement to undertake measures to get back into compliance, and sanctions.

Regulators focus on all polluters under federal jurisdiction, specifically, plants based on environmental impacts, prior record of compliance with the environmental legislation, and toxic residuals. Typically, inspectors target major polluters for annual visits, but a facility may be visited more than once in the same year. Initial visits can be due to regular monitoring or due to emergency or citizen complaints. Initial visits are followed by verification visits, after the completion of which firms are obligated by law to take measures to get back into compliance or sanctions in the form of fines are imposed as a resolution to administrative actions of enforcement. Camacho (2016) finds that verification visits are for priority violations as outcomes from the first or initial visit.

We obtained detailed data on plant name, address, type of facility, inspections program, type of inspection, the outcome of the visit, final resolution, and fines imposed through a Transparency request. We examine inspections and fines data from 2000 to 2016. Toxic waste or residuals program registered the most inspection activities, 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.

On average, PROFEPA conducted about 7000 annual visits. 57% were regular monitoring, the remaining initial visits were 7% citizen complaints, and 4% emergencies; 32% were follow up verification visits.[6] Of the total inspection visits, on average, plants got fined about 30% of the time every year. From the data, plants can be fined more than once within a year for violations under different inspections programs, and the amount fined might be identical under all programs. The fines data exhibit extreme skewness; only a few manufacturers faced significant penalties.

3B. RETC data

The self-reported pollution database on toxic pollution called the Pollutant Release and Transfer Registry (*Registro de Emisiones y Transferencias de Contaminantes*, RETC) is available from the ministry of environment of Mexico (*Secretaria de Medio Ambiente y Recursos Naturales*, or SEMARNAT). The database 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. Based on the frequency of different pollutants and media reported, we focus on seven toxic materials discharged in the water. It covers eleven industrial sectors that are major toxic polluters, defined as plants discharging 1 kilogram of arsenic, cadmium, chromium, lead, mercury, and nickel, annually (and more than 100 kilograms of cyanide).

Since mandatory reporting began, the sample of plants reporting positive amounts of toxic pollution varied remarkably from one year to the next.[7] We access the database in 2017, with data until 2015. We include direct discharges and indirect discharges through sewage as it enters water

[6] Majority of the inspection visits were categorized as minor irregularities (51.5%) followed by 36% in the no irregularities category, and the remaining 12.5% under either one of the urgent or priority actions.
[7] We present a Missing Pollution Reports Appendix to investigate patterns in the missing pollution data.

bodies without treatment or recycling (CEC, 2011). On average, the number of plants reporting water pollution for at least one of the seven toxic pollutants was around 1000 facilities per year. However, the panel was unbalanced, exhibiting considerable variation over the years covered. The number of facilities reporting peaked at 1,388 facilities with water pollution reports in 2006.

We undertook manual consolidation of the annual databases to create a facility level panel. Each physical plant or business that changed names, ownership, even sector was assigned a new identifier in the RETC database. 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, these plants are located mostly near large urban areas. The top five states were the State of Mexico (18%), Tamaulipas (10%), Mexico City and Nuevo Leon (9%), and Jalisco (8%).

3C. Sociodemographic data

The socioeconomic, demographic variables are from two censuses and one *conteo* year (2000, 2010, and 2005) that are relevant for pollution from 2004 to 2015. We choose eleven census variables to incorporate indicators of education, health, and housing conditions (see Table 1). We also include population density as a control for the population exposed to local pollution. We assign municipality level socio-economic data to each plant. We include lagged rather than contemporaneous values on socioeconomic features to avoid reverse causality of sorting in response to local conditions such as pollution (Chakraborti and Shimshack, 2020). We create three bins of four years of pollution to divide up the twelve years of data evenly.

3D. Summary Statistics

Our final sample is a panel of 3432 toxics releasing plants, over 2004-2015, on inspections at each plant under various monitoring programs, the outcome of the visit or degree of violation, initial or follow-up visit, and the amount fined as the final resolution. To fulfill our empirical strategy, we present all descriptive statistics of regulatory actions based on toxics inspections programs and all other programs grouped as non-toxics.[8] Table 1 presents the plant level summary statistics on regulatory actions for the toxic inspections program. On average, a plant got inspected 0.05 times annually. Overall, a plant got fined much less frequently than it got inspected. On average, a plant faced a financial penalty of 0.02 times a year. Of the positive fined amounts, on average, a plant faced fines of 183 USD in real terms, yearly.

Table 1 also presents the relevant statistics for the other regulatory activities used in the estimations, namely lagged inspections, lagged fined counts, and lagged fined amounts, on itself and others in the same municipality. We consider two lag lengths of the past three years and the past two years as regulatory processes often spilled across years. For the past three years lag, a plant was inspected 0.14 times and fined 0.05 times with an average fine of $202 for positive fines. For the past two years lag, a plant was inspected 0.09 times and fined 0.04 times, with an average positive fine of $198. For the past three years lag, the average number of inspections on all other plants in the same municipality was 10.80, the average number of fines was 4.96, and an average positive fined amount of $650. For the past two years lag, the average number of inspections on all other plants in the same municipality was 4.70, the average number of fines was 2.15, and an average positive fined amount of $520.

The socioeconomic characteristics show considerable variability for the sample of plants in the regression. The average plant is in a community with a low share of population over 15 that is illiterate (5%), a low proportion of 6 to 14-year-olds that do not attend school (5%), a much higher share of over 15 with primary education incomplete (41%), a high share of population

[8] Further descriptive statistics and graphs are presented in the Data Appendix.

without health services (39%), a low share of households with mud floor (5.5%), a low share of households without septic connection (7%), a low share of households without piped water (8%), a low share of households without adequate drainage (8.6%), a much smaller share of households without electricity (3%), a much higher share of households without washing machine (33%), a modest share of households without refrigerator (18%), and average population density of 2,605 people per square kilometer. Since our sample is from urban municipalities, the average population density is comparable to the population density of metropolitan areas.

Last, we present the summary statistics of the seven toxic pollutants. We preprocess the data with 0.5% trimming (Chakraborti and Shimshack, 2020). In the raw data, the maximum value for each of the seven pollutants was 40 to 80 standard deviations larger than the mean. The bottom panel of Table 1 summarizes the average toxic water pollution discharges across facilities. The pollution data also shows considerable variability depending on the toxic substance considered. 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 matched with socioeconomic and inspections and fines data, mean discharges of nickel, lead, chromium, cadmium, cyanide, arsenic, and mercury are 57, 39, 35, 14, 9.8, 4.5, and 1 kilogram per year.

Table 1. Summary Statistics

Variables	Obs.	Mean	Std. Dev.	Max.
INSPECTIONS, TOXICS				
Annual inspections on itself (#)	11,860	0.05	0.21	1.00
Past 3 yr. inspections on itself (#)	11,860	0.14	0.41	3.00
Past 3 yr. inspections on others (#)	11,860	10.80	29.90	172.00
Past 2 yr. inspections on itself (#)	11,860	0.09	0.32	2.00
Past 2 yr. inspections on others (#)	11,860	4.70	12.93	81.00
FINES IMPOSED, TOXICS				
Annual fines on itself (#)	11,860	0.02	0.14	1.00
Past 3 yr. fines on itself (#)	11,860	0.05	0.25	3.00
Past 3 yr. fines on others (#)	11,860	4.96	14.28	81.00
Past 2 yr. fines on itself (#)	11,860	0.04	0.20	2.00
Past 2 yr. fines on others (#)	11,860	2.15	6.46	40.00
AMOUNT FINED, TOXICS				
Annual fines on itself (2010 USD)	11,860	3.59	247.71	22789.46
Annual fines on itself, given fines>0	233	182.50	1761.73	22789.46
Past 3 yr. fines on itself (2010 USD)	11,860	9.50	391.52	22789.46
Past 3 yr. fines on itself, given fines>0	558	201.84	1795.74	22789.46
Past 3 yr. fines on others (2010 USD)	11,860	257.80	2204.32	23236.48
Past 3 yr. fines on others, given fines>0	4,702	650.26	3464.45	23236.48
Past 2 yr. fines on itself (2010 USD)	11,860	7.08	330.75	22789.46
Past 2 yr. fines on itself, given fines>0	424	197.90	1740.41	22789.46
Past 2 yr. fines on others (2010 USD)	11,860	181.94	1838.97	23236.48
Past 2 yr. fines on others, given fines>0	4,149	520.08	3080.99	23236.48
SOCIO-DEMOGRAPHICS				
Population over 15, illiterate (%)	11,860	5.02	3.53	45.94
6 to 14-year-olds do not attend school (%)	11,860	4.85	2.14	22.02
Over 15 primary education incomplete (%)	11,860	40.68	11.59	90.32
Population without health services (%)	11,860	39.44	13.49	96.88
Households with mudfloor (%)	11,860	5.46	6.27	79.86
Households without septic connection (%)	11,860	7.17	6.56	78.77
Households without piped water (%)	11,860	8.11	9.43	84.82
Households without adequate drainage (%)	11,860	8.61	11.08	92.24
Households without electricity (%)	11,860	3.28	4.06	71.54
Households without washing machine (%)	11,860	32.72	15.43	99.05
Households without refrigerator (%)	11,860	17.80	12.92	96.73
Population Density, thousands/sq.km.	11,860	2.61	4.21	19.49
POLLUTION (kg)				
Arsenic^	8,681	4.49	36.61	972.12
Cadmium	8,074	14.44	100.51	2197.09
Chromium	8,312	35.04	258.27	5253.00
Cyanide^	8,684	9.81	69.90	1648.64
Lead	9,037	39.25	279.98	5838.00
Mercury^	8,232	1.02	8.53	205.61
Nickel	9,279	57.45	380.41	7586.50

NOTES: The summary statistics are for 3,432 facilities across Mexico. ^ denotes results do not include the years 2014 and 2015 for arsenic, cyanide, and mercury.

4. EMPIRICAL STRATEGY

In this section, we test some hypotheses on environmental regulation in Mexico. Our conclusions derive from the results of the regulatory actions and self-reported pollution models. First, we empirically model the determinants of inspections and enforcement actions like fines implemented by the regulatory agency, PROFEPA. Second, we model the impacts of inspections and fines on annual reporting of seven toxic substances by major polluters in Mexico.

We adopt two strategies to address the endogeneity of inspections and fines in the pollution model. Previous studies refer to the targeting of plants by inspectors based on the type of manufacturing or size of the operation. For example, a large chemical plant may report higher toxic pollution concurrently with higher inspections (or fines due to the higher environmental or health risks). Shimshack and Ward (2005) include instruments, i.e., regulatory actions that are correlated with inspections and fines directed at the specific plant but not correlated with the idiosyncratic targeting of the plant. Adopting this approach, we include inspections and fines under the toxics program targeted at all other plants in the same municipality as higher inspections (and fines) in the municipality is likely correlated with higher inspections (and fines) against the specific plant but not with higher pollution emissions of the plant.

Second, we exploit the exogeneity of all other regulatory actions taken against an individual polluter that might not be influenced by the toxic discharges of the plant. To this extent, we consider inspections and fines imposed on each plant due to all programs other than the toxic-residuals inspection program. We consider these regulatory actions as appropriate instruments as a chemical plant can face inspection visits under toxic residuals and high-risk or environmental impact monitoring programs simultaneously. However, higher toxic water pollution discharge of the plant may not influence regulatory activities under other programs.

4A. PROFEPA Inspections & Fines

From PROFEPA guidelines, we know that inspectors typically target high risk, toxics generating industries, e.g., chemical industry and those with potential environmental (health) impacts on the population. However, we cannot include plant fixed effects in a probit estimation due to the incidental parameters problem. Our first strategy to control for targeting related to the manufacturing facility is to estimate the inspection (and fines) models for the seven toxic pollutants separately. Industrial facilities in the same sector often release a common set of toxic substances as residuals of their manufacturing process. However, this comes at the cost of efficiency loss as the sample size reduces significantly because not all plants in our sample report all seven pollutants each year.

$$Dep_{it} = \alpha + \mathrm{B}R_{it'} + \Gamma R_{-it'} + \Phi \mathrm{X}_{it} + \mu y_t + \varepsilon_{it} \tag{1}$$

We estimate three separate models: annual inspections, annual fines, and annual fined amount. For the first estimation, the dependent variable, $Insp_{it}$, is toxic inspections at plant i and year t, a 0/1 binary variable. It takes a value of 1 if the plant is inspected under the toxics program during a year and 0 if the plant did not witness any toxic inspection visit in that same year. For the second estimation, the dependent variable $Fine_{it}$ is a 0/1 binary outcome that takes the value one if plant i receives a fine in year t and zero if plant i does not receive a fine in year t. For the third estimation, the dependent variable is the log of the monetary fine imposed on plant i and year t with $Fine_{it} \geq 0$.

The inspection and fines variables are captured by $R_{it'}$, in equation (1). We control plant-specific targeting by including lagged $t' = \{t-1, t-2, t-3\}$ regulatory actions, such as the total number of inspections, total number of priority violations as the outcome of inspections, sum of total fines imposed. $R_{it'}$ includes lagged inspections conducted at plant i, lagged priority violations as an outcome of the inspection visit at plant i, and log of lagged amount fined at plant i. We then sum over the past three and two years. Consequently, identification comes from time variation in plant-specific targeting. The regulatory actions for toxic inspections program and all other non-toxic inspections programs are separated. In our sample, 30% of the plants got inspected for toxics and non-toxic programs simultaneously. Of these, 30% got fined for both toxics and non-toxics in the same year. Of these, close to 50% got fined identical amounts under toxics and non-toxics during the same year.

To control municipality level variations due to changes in budget or political situation, we include the total number of inspections and fines imposed on all other plants in the same municipality. Higher inspections (and enforcement actions if found in violation) targeted at all plants in the same jurisdiction might imply higher regulatory activities at the specific plant. In equation (1), $R_{-it'}$ includes lagged toxic inspections conducted on all other plants in the same municipality and log of lagged amount fined under the toxic program on all other plants in the same municipality. We then sum over the past three and two years in separate estimations. We focus on toxic inspections to capture general regulatory pressure to avoid multicollinearity problems as an increased budget increase all types of inspections.

In equation (1) above, X_{it} is the vector of twelve lagged socioeconomic, demographic variables including population density of the municipality of plant i, and drawn from the census years 2000, 2005, and 2010. We include year fixed effects to control all annual changes in regulatory activities that are not specific to the municipality.[9] Finally, we cluster standard errors at the state level to control for arbitrary correlation across plants in the same state.

[9] We tried political cycles based on presidential and midterm elections and these coefficients were not significant either using turnout data at the municipality level.

First, we model annual visits by PROFEPA inspectors under the toxic-residuals inspection program at each plant in our sample.[10] Panel A of Table 2 presents the inspection models for the past three years' lagged values and Panel B for the past two years' lagged values. The coefficients presented are the marginal effects calculated at mean values. In general, plants with a higher frequency of priority violations for both toxic and non-toxic programs faced a higher probability of being inspected. Results show that if a plant has one more violation under the toxic program in the past, the probability that it receives an inspection visit in the current year increases by around one percentage point for all seven toxics. If a plant has one more violation under the non-toxic program in the past, the probability that it receives an inspection visit in the current year increases by one to two percentage points for all seven toxics. We interpret this result as evidence of targeting by regulators based on significant non-compliance.

In terms of general regulatory activities on all other facilities in the same municipality, the total number of past inspections on others is significant in determining current inspections. Results in Panel A and Panel B of Table 2 show that one more inspection visit on others in the past results in a higher probability of being inspected by 0.1 percentage points for all seven toxics. We interpret these results as higher inspections on all other polluters in the same municipality denotes greater regulatory resources in general, leading to an increase in the probability of inspections of individual plants.

[10]In the Appendix Tables 2 through 5 we estimate two inspections model differentiated by type of inspection visits namely first or initial visit (regular protocol or emergency or citizen complaint) or follow-up verification visit. Initial visits as part of regular monitoring are further differentiated from initial visits due to citizen complaints and emergencies.

Table 2. Inspections Models

Panel A: RE Probit Inspections, Marginal effects at mean values, regulatory actions lagged three years							
DEP.VAR: Toxic Inspections:	As^	Cd	Cr	CN-^	Pb	Hg^	Ni
Toxic Inspections	0.009	0.012	0.012	0.005	0.011	0.010	0.010
	(0.007)	(0.009)	(0.009)	(0.006)	(0.008)	(0.008)	(0.009)
Non-toxic Insp.	-0.005	-0.004	-0.003	-0.008	0.000	-0.005	-0.001
	(0.010)	(0.011)	(0.009)	(0.008)	(0.010)	(0.009)	(0.008)
Toxic Violations	0.008*	0.010**	0.009**	0.009***	0.009*	0.008**	0.009*
	(0.004)	(0.005)	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)
Non-toxic Viol.	0.011**	0.013**	0.012**	0.013***	0.011*	0.009*	0.011**
	(0.005)	(0.007)	(0.005)	(0.004)	(0.006)	(0.006)	(0.005)
Toxic Inspections	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***
on others	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Toxic Fines	0.003	0.003	0.003	0.002	0.003	0.002	0.003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Non-toxic Fines	0.0010	-0.000	0.000	0.001	-0.001	0.001	-0.000
	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Toxic Fines	0.000	0.000	-0.000	0.000	0.000	0.000	-0.000
on others	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Obs.	8,681	8,074	8,312	8,684	9,037	8,232	9,279
Panel B: RE Probit Inspections, Marginal effects at mean values, regulatory actions lagged two years							
DEP.VAR: Toxic Inspections:	As^	Cd	Cr	CN-^	Pb	Hg^	Ni
Toxic Inspections	0.014	0.014	0.015	0.011	0.011	0.011	0.011
	(0.009)	(0.011)	(0.009)	(0.008)	(0.010)	(0.009)	(0.010)
Non-toxic Insp.	-0.002	-0.001	0.009	0.000	0.005	0.001	0.005
	(0.010)	(0.013)	(0.010)	(0.008)	(0.011)	(0.009)	(0.009)
Toxic Violations	0.011**	0.013***	0.011**	0.010***	0.013***	0.012***	0.012**
	(0.005)	(0.005)	(0.005)	(0.004)	(0.005)	(0.004)	(0.005)
Non-toxic Viol.	0.014**	0.018**	0.012*	0.012**	0.014**	0.012**	0.012**
	(0.006)	(0.008)	(0.006)	(0.005)	(0.007)	(0.006)	(0.006)
Toxic Inspections	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***
on others	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Toxic Fines	0.003	0.005**	0.005*	0.003	0.005**	0.003	0.004
	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)
Non-toxic Fines	0.003	0.000	-0.001	0.003	-0.001	0.003	0.010
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Toxic Fines	0.000	0.001	0.000	0.001	0.002	0.001	0.000
on others	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
Obs.	8,681	8,074	8,312	8,684	9,037	8,232	9,279

NOTES: Standard errors clustered at state level in parentheses; *** p<0.01, ** p<0.05, * p<0.1. ^ denotes results do not include the years 2014 and 2015 for arsenic, cyanide, and mercury.

The socioeconomic variables are seldom significant, but we find some evidence of higher monitoring activities in more marginalized communities (also reported in Escobar and Chavez 2013). Statistically significant coefficients on the proportion of the population between 6 and 14 years old that do not attend school (for arsenic, cadmium, and nickel) and proportion of households without washing machine (for arsenic, cadmium, lead, mercury, and nickel) show that plants located in municipalities with higher shares face more inspection visits. Results are weaker for the past two years' lag length.

We present marginal effects calculated at mean values for the binary fined models in Table 3. Like the inspection models, past violations for toxic inspections raise the probability of current monetary fines imposed by 3-4 percentage points. Unlike the inspection results, past violations for non-toxic inspections are rarely statistically significant. We infer that enforcement actions depend on violations specific to the program. Regarding the general regulatory measures, like the inspection models, we find that one more inspection visit on others in the past, on all other facilities in the same municipality results in a higher probability of being fined by strictly less than 0.1 percentage point (statistically significant for all seven toxics). We interpret this result as increased financial resources of the regulatory agency resulting in increased inspections and increased discovery of potential violations and fines imposed.

Like the inspection results, plants located in municipalities with higher shares of population six between 14 years that do not attend school or households without washing machine experience more fines imposed. However, a higher share of the population over 15 years who are illiterate have the opposite sign (negative) than expected.

Table 3. Fined Models

Panel A: RE Probit Fined, Marginal effects at mean values, regulatory actions lagged three years							
DEP.VAR: Toxic Fines:	As^	Cd	Cr	CN-^	Pb	Hg^	Ni
Toxic Inspections	-0.001	0.000	0.000	-0.001	0.001	0.000	-0.001
	(0.003)	(0.004)	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)
Non-toxic Insp.	-0.003	-0.003	-0.004	-0.005	0.002	-0.002	-0.001
	(0.004)	(0.005)	(0.004)	(0.003)	(0.004)	(0.004)	(0.004)
Toxic Violations	0.003*	0.003*	0.003	0.003*	0.003	0.003	0.004*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Non-toxic Viol.	0.003	0.004	0.004*	0.004*	0.002	0.002	0.002
	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Toxic Inspections	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
on others	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Toxic Fines	0.002	0.002	0.002	0.001	0.002	0.001	0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
Non-toxic Fines	0.001	0.001	0.001	0.001	0.000	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Toxic Fines	0.000	0.001	0.000	0.000	0.001	0.000	0.000
on others	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Obs.	8,681	8,074	8,312	8,684	9,037	8,232	9,279

Panel B: RE Probit Fined, Marginal effects at mean values, regulatory actions lagged two years							
DEP.VAR: Toxic Fines:	As^	Cd	Cr	CN-^	Pb	Hg^	Ni
Toxic Inspections	0.002	0.002	0.001	0.003	0.002	0.002	0.000
	(0.004)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Non-toxic Insp.	0.002	0.001	0.001	-0.002	0.007	0.002	0.003
	(0.004)	(0.006)	(0.005)	(0.004)	(0.006)	(0.005)	(0.004)
Toxic Violations	0.004	0.004	0.004*	0.004*	0.004	0.004	0.005**
	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Non-toxic Viol.	0.003	0.004	0.004	0.004	0.002	0.002	0.003
	(0.002)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Toxic Inspections	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***
on others	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Toxic Fines	0.002	0.002*	0.001	0.001	0.002	0.001	0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Non-toxic Fines	0.002	0.001	0.000	0.002	0.000	0.002	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Toxic Fines	0.000	0.001	0.000	0.001	0.001	0.000	0.000
on others	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Obs.	8,681	8,074	8,312	8,684	9,037	8,232	9,279

NOTES: Standard errors clustered at state level in parentheses; *** p<0.01, ** p<0.05, * p<0.1. ^ denotes results do not include the years 2014 and 2015 for arsenic, cyanide, and mercury.

Table 4 presents the results of the amount fined models. We present estimation results upon fitting a Tobit model censored at zero fines. Like the binary fined models, past violations under the toxics program increase the fined amounts (for all seven toxics). We find that one more priority violation in the past result in an increase in amount fined by 1%. The coefficients for violations under non-toxic programs are also positive but rarely statistically significant. General regulatory presence captured by higher toxic inspections on others in the same municipality leads to a higher fined amount by 0.1%.

Socioeconomic variables are again rarely significant, except for plants located in municipalities with higher shares of the population between 6 and 14 that do not attend school facing higher fined amounts. While plants in municipalities with higher shares of the population over 15 who are illiterate face lower fined amounts.

We infer that environmental regulation in Mexico is broadly consistent with the compliance history of the individual polluter as higher past violations under toxic monitoring programs result in a higher probability of current inspections, fines, and fined amount. Higher past violations detected under all other inspection programs result in a higher probability of inspections only. Enforcement actions such as fines and the amount fined depend on its degree of severity or the extent of violation under the specific monitoring program. Priority violations under all other programs are primarily instruments for targeting by regulators. Regarding general regulatory measures, an increased number of toxic inspections on other facilities in the same municipality results in a higher probability of current inspections, fines, and amount fined. We infer that greater regulatory resources imply increased activities on the plant itself.

Table 4. Amount Fined Models

Panel A: Tobit Amount Fined, Marginal effects at mean values, regulatory actions lagged three years							
DEP.VAR: Log Amount Fined:	As^	Cd	Cr	CN-^	Pb	Hg^	Ni
Toxic Inspections	-0.380	-0.211	-0.221	-0.465	-0.077	-0.153	-0.598
	(0.639)	(0.654)	(0.710)	(0.673)	(0.608)	(0.634)	(0.676)
Non-toxic Insp.	-0.680	-0.630	-0.856	-1.263	0.400	-0.512	-0.271
	(0.806)	(0.797)	(0.854)	(0.832)	(0.737)	(0.814)	(0.816)
Toxic Violations	0.824***	0.712**	0.760**	0.925***	0.659**	0.816***	0.919***
	(0.305)	(0.305)	(0.333)	(0.316)	(0.291)	(0.307)	(0.318)
Non-toxic Viol.	0.723	0.772	0.956*	0.934*	0.333	0.484	0.600
	(0.486)	(0.476)	(0.506)	(0.491)	(0.456)	(0.489)	(0.502)
Toxic Inspections on others	0.087***	0.074***	0.093***	0.093***	0.070***	0.088***	0.081***
	(0.022)	(0.019)	(0.023)	(0.023)	(0.017)	(0.022)	(0.019)
Toxic Fines	0.387	0.428*	0.372	0.378	0.351	0.227	0.454*
	(0.236)	(0.231)	(0.258)	(0.237)	(0.216)	(0.230)	(0.244)
Non-toxic Fines	0.255	0.171	0.105	0.256	0.0572	0.327	0.0791
	(0.240)	(0.240)	(0.260)	(0.241)	(0.225)	(0.233)	(0.246)
Toxic Fines on others	0.097	0.184*	0.068	0.046	0.139	0.090	0.100
	(0.108)	(0.107)	(0.115)	(0.111)	(0.0993)	(0.110)	(0.107)
Obs.	8,681	8,074	8,312	8,684	9,037	8,232	9,279

Panel B: Tobit Amount Fined, Marginal effects at mean values, regulatory actions lagged two years							
DEP.VAR: Log Amount Fined:	As^	Cd	Cr	CN-^	Pb	Hg^	Ni
Toxic Inspections	0.244	0.192	-0.002	0.451	-0.0253	0.259	-0.150
	(0.768)	(0.803)	(0.874)	(0.789)	(0.737)	(0.752)	(0.835)
Non-toxic Insp.	0.277	-0.0759	0.0622	-0.548	0.964	0.299	0.325
	(0.915)	(0.966)	(1.052)	(0.954)	(0.889)	(0.920)	(0.989)
Toxic Violations	0.724**	0.751**	0.853**	0.784**	0.784**	0.804**	0.978**
	(0.350)	(0.377)	(0.408)	(0.358)	(0.346)	(0.343)	(0.388)
Non-toxic Viol.	0.512	0.826	0.860	0.731	0.448	0.456	0.526
	(0.554)	(0.582)	(0.633)	(0.557)	(0.548)	(0.557)	(0.611)
Toxic Inspections on others	0.118***	0.083***	0.107***	0.116***	0.075***	0.113***	0.106***
	(0.029)	(0.031)	(0.036)	(0.028)	(0.025)	(0.029)	(0.027)
Toxic Fines	0.334	0.449*	0.265	0.253	0.409*	0.156	0.371
	(0.261)	(0.251)	(0.294)	(0.259)	(0.237)	(0.253)	(0.274)
Non-toxic Fines	0.332	0.191	0.0826	0.376	0.010	0.376	0.167
	(0.266)	(0.263)	(0.294)	(0.266)	(0.250)	(0.258)	(0.272)
Toxic Fines on others	0.334	0.449*	0.265	0.253	0.409*	0.156	0.371
	(0.261)	(0.251)	(0.294)	(0.259)	(0.237)	(0.253)	(0.274)
Obs.	8,681	8,074	8,312	8,684	9,037	8,232	9,279

NOTES: Standard errors clustered at state level in parentheses; *** p<0.01, ** p<0.05, * p<0.1. ^ denotes results do not include the years 2014 and 2015 for arsenic, cyanide, and mercury.

4B. Environmental Deterrence of Monitoring and Enforcement

In this section, we investigate whether regulatory actions, as captured by PROFEPA monitoring and enforcement activities like fines imposed, have any environmental deterrence impact. We test the impact of monetary sanctions and inspections conducted on itself and others in the same municipality on self-reported toxic pollution levels. We know that high levels of self-reported toxic emissions do not result in inspections and enforcement actions.[11] Polluters do not have the typical incentives to under-report pollution based on expected penalties of non-compliance with maximum allowable limits on toxic pollutants discharged.

Equation (2) below presents the panel data model of toxic releases. Each of the seven toxic substances released into the water is estimated separately. For facility i in year t, we regress the log of toxic pollutants discharged into the water on past monitoring and enforcement actions on itself and others in the same municipality as the plant, controlling other factors that influence pollution levels. In equation (2), $R_{it'}$ includes the total number of inspections conducted on itself, total number of violations as an outcome of inspections on itself, the log of the sum of monetary fines imposed on the plant; $R_{-it'}$ includes the total number of inspections conducted on others in the same municipality and the log of the total amount fined on others in the same municipality. Like the inspections and fined models, we consider two lag lengths of past three- and two-years' averages for the variables capturing regulatory activities. Plant fixed effects α_i capture all time-invariant plant-specific (e.g., size, age, type of industrial facility) and location-specific factors (e.g., political jurisdiction, state, distance to large metropolitan cities). Lagged socioeconomic

[11] Results not presented in the paper show that upon including past pollution in the inspections models, the coefficients are negative but not statistically significant from zero for all seven toxic substances. In the fined models, the coefficients on past pollution is negative across all different specifications (significant only for arsenic and mercury). In other words, higher pollution levels reported is linked to lower inspections and fines imposed on the plant.

variables X_{it} capture any differences in plant-level pollution based on community characteristics. Year fixed effects control for annual changes in toxic releases not specific to a plant. The error term is clustered within states to account for arbitrary correlations across facilities in the same state.

$$ln(tox)_{it} = \alpha_i + \mathrm{B}R_{it'} + \Gamma R_{-it'} + \Phi \mathrm{X}_{it} + \mu y_t + \varepsilon_{it} \tag{2}$$

Table 5 Panel A presents the within-group panel analyses for the lagged inspections and fined values over the past three years. Panel B presents the within-group results with the lagged inspections and fined values for the past two years. Overall, we find that regulator reputation effects captured by increasing amounts fined on all other major polluters in the same municipality exert a significant environmental deterrence effect on toxic discharges of four out of the seven pollutants (for the remaining three toxic pollutants, results are negative but not always significant). The coefficients in Panel A of Table 5 show that a 1% increase in amount fined in the past three years on other facilities in the same municipality results in a decline in chromium and lead discharges by 0.07% per year, cadmium discharges by 0.06% per year, and cyanide discharges by 0.05% per year. For the past two years, the coefficient on lagged fined amount on others is consistently negative and significant for four out of the seven toxic pollutants. Estimated coefficients show that a 1% increase in the amount fined in the past two years on others results in a decline in chromium discharges by 0.09%, cadmium discharges by 0.07% per year, lead discharges by 0.06% per year, and cyanide discharges by 0.05% per year. Though the coefficients are small in magnitude, these changes might be significant as toxic substances are damaging even at minimal concentrations.

Among the other regulatory variables, only recent regulatory activities seem to exert any statistically significant impact on pollution levels. The total number of past two years violations under toxic programs increase reported pollution that is statistically significant for three out of the seven toxic pollutants. Results show that one more priority violation under the toxic program leads to an increase in annual cadmium discharges by 0.20%, cyanide discharges by 0.15%, and nickel discharges by 0.17%. However, the magnitude is even smaller and switch sign for arsenic and mercury. The total number of past two years violations under all other programs also increase the reported pollution level that is statistically significant for five out of the seven toxic pollutants. Results show that one more priority violation under other programs lead to plants increasing their cadmium discharges by 0.63% per year, chromium discharges by 0.54% per year, nickel discharges by 0.45% per year, cyanide discharges by 0.43% per year, and lead discharges by 0.40% per year.

We infer that violations as an outcome of inspections conducted on the plant under either toxic or other monitoring programs not only lead to a higher frequency of pollution reporting (missing results in the Appendix Table 6); they also result in higher pollution levels reported. Since the monitoring programs in Mexico do not enforce whether plants discharge below a certain level of pollutants (e.g., plant-specific effluent limits), the main goal is to promote self-reporting protocols undertaken by all major toxic polluters. We infer that significant violations detected at a plant result in better environmental management practices such as regular reporting and accurate measurements on-site or at licensed laboratories.[12]

[12] Lagged socioeconomic variables (not presented in the table) are rarely significant in the pollution models.

Table 5. Environmental Pollution, Panel Data Models

Panel A: Panel regressions, facility by year data, regulatory actions lagged three years

DEP.VAR: The log of:	As^	Cd	Cr	CN-^	Pb	Hg^	Ni
Toxic Inspections	-0.180	-0.192	-0.056	-0.202	-0.240	-0.259	-0.243
	(0.270)	(0.277)	(0.284)	(0.294)	(0.224)	(0.279)	(0.243)
Non-toxic Insp.	-0.068	-0.043	-0.099	0.051	-0.110	0.017	0.146
	(0.257)	(0.311)	(0.333)	(0.317)	(0.230)	(0.309)	(0.306)
Toxic Violations	-0.002	0.121	0.046	0.142	0.106	0.096	0.060
	(0.098)	(0.122)	(0.112)	(0.119)	(0.092)	(0.112)	(0.113)
Non-toxic Viol.	0.089	0.225	0.200	0.166	0.198	0.137	0.093
	(0.177)	(0.186)	(0.197)	(0.267)	(0.138)	(0.213)	(0.207)
Toxic Inspections on others	0.002	0.001	-0.000	0.002	-0.000	0.002	-0.000
	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Toxic Fines	0.127	0.020	-0.018	-0.059	0.022	0.058	0.121
	(0.110)	(0.103)	(0.101)	(0.135)	(0.095)	(0.116)	(0.110)
Non-toxic Fines	0.101	-0.139	-0.172*	-0.108	-0.151	-0.097	-0.236
	(0.100)	(0.110)	(0.097)	(0.162)	(0.128)	(0.122)	(0.144)
Toxic Fines on others	-0.019	-0.062*	-0.073**	-0.051*	-0.073**	-0.020	-0.033
	(0.035)	(0.034)	(0.032)	(0.030)	(0.032)	(0.034)	(0.031)
R^2	0.01	0.05	0.05	0.01	0.04	0.01	0.05
Obs.	8,681	8,074	8,312	8,684	9,037	8,232	9,279

Panel B: Panel regressions, facility by year data, regulatory actions lagged two years

DEP.VAR: The log of:	As^	Cd	Cr	CN-^	Pb	Hg^	Ni
Toxic Inspections	-0.263	-0.392	-0.327	-0.458*	-0.318	-0.193	-0.560***
	(0.275)	(0.255)	(0.259)	(0.268)	(0.214)	(0.232)	(0.186)
Non-toxic Insp.	-0.212	-0.664**	-0.599*	-0.229	-0.268	0.050	-0.314
	(0.219)	(0.288)	(0.296)	(0.231)	(0.275)	(0.269)	(0.355)
Toxic Violations	-0.007	0.202**	0.118	0.150**	0.082	-0.009	0.169**
	(0.078)	(0.079)	(0.083)	(0.072)	(0.069)	(0.084)	(0.083)
Non-toxic Viol.	0.230	0.632***	0.539***	0.433**	0.376**	0.227	0.451*
	(0.138)	(0.162)	(0.183)	(0.171)	(0.182)	(0.142)	(0.227)
Toxic Inspections on others	0.001	-0.004	-0.001	-0.000	-0.006	-0.000	-0.004
	(0.004)	(0.009)	(0.006)	(0.005)	(0.006)	(0.004)	(0.005)
Toxic Fines	0.117	-0.009	0.032	0.035	0.044	0.086	0.125
	(0.096)	(0.108)	(0.103)	(0.101)	(0.084)	(0.095)	(0.112)
Non-toxic Fines	0.021	-0.141	-0.145	-0.136	-0.188	-0.127	-0.238
	(0.091)	(0.127)	(0.123)	(0.168)	(0.152)	(0.139)	(0.156)
Toxic Fines on others	-0.025	-0.067**	-0.085***	-0.050*	-0.060**	-0.008	-0.041
	(0.029)	(0.033)	(0.030)	(0.029)	(0.027)	(0.027)	(0.031)
R^2	0.01	0.05	0.05	0.01	0.04	0.01	0.05
Obs.	8,681	8,074	8,312	8,684	9,037	8,232	9,279

NOTES: Standard errors clustered at state level in parentheses; *** p<0.01, ** p<0.05, * p<0.1. ^ denotes results do not include the years 2014 and 2015 for arsenic, cyanide, and mercury.

As a robustness check, we estimate an alternate specification, with state-by-year interactions, y_{st} in equation (3) below. In these models, we control time-varying state-specific factors such as changes in state budgets, variations in overall regulatory stringency, environmental attitudes within states, or state-level changes in the economy. The deterrence impact of general fines imposed on other facilities is robust to controlling for all time-varying changes or trends within states (as seen in Table 6). Similarly, recent past violations over the last two years under toxic and non-toxic programs increase pollution levels; past inspections under toxic and non-toxic programs lead to a decline in pollution levels (significant for only two pollutants).

$$ln(tox)_{it} = \alpha_i + \mathrm{B}R_{it'} + \Gamma R_{-it'} + \Phi \mathrm{X}_{it} + \mu y_{st} + \varepsilon_{it} \tag{3}$$

To summarize, our strongest evidence is that of the environmental deterrence impact arising due to the regulator reputation effects captured by increased fined amounts imposed on all other plants in the same municipality. We know that a higher number of priority violations at a plant leads to a higher probability of fines and amounts fined. Hence, higher fined amounts imposed on all plants in the same municipality means that more plants in the municipality are not complying with their reporting protocols such as regular measurements or taking samples and sending to authorized labs. The plant itself, in response to an increase in expected costs of non-compliance, engage in activities to improve environmental compliance. In case the plant itself is in violation, that leads to increased efforts to meet PROFEPA reporting guidelines and requirements through an increase in reported pollution levels.

Table 6. Environmental Pollution Models (including state-by-year interactions)

Panel A: Panel regressions, facility by year data, regulatory actions lagged three years

DEP.VAR: The log of:	As^	Cd	Cr	CN-^	Pb	Hg^	Ni
Toxic Inspections	-0.210	-0.335	-0.090	-0.296	-0.297	-0.331	-0.313
	(0.272)	(0.304)	(0.308)	(0.313)	(0.261)	(0.284)	(0.249)
Non-toxic Insp.	-0.146	-0.279	-0.245	-0.110	-0.250	-0.048	-0.024
	(0.273)	(0.343)	(0.349)	(0.305)	(0.262)	(0.330)	(0.310)
Toxic Violations	0.063	0.191	0.081	0.205	0.153	0.136	0.087
	(0.090)	(0.132)	(0.114)	(0.121)	(0.095)	(0.110)	(0.112)
Non-toxic Viol.	0.136	0.343*	0.293	0.227	0.288*	0.178	0.219
	(0.172)	(0.174)	(0.197)	(0.258)	(0.143)	(0.213)	(0.195)
Toxic Inspections on others	0.001	0.001	0.001	0.001	0.000	0.001	-0.001
	(0.002)	(0.004)	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)
Toxic Fines	0.063	0.023	-0.044	-0.073	0.006	0.047	0.129
	(0.115)	(0.106)	(0.104)	(0.135)	(0.100)	(0.117)	(0.117)
Non-toxic Fines	0.117	-0.141	-0.133	-0.107	-0.119	-0.099	-0.234
	(0.103)	(0.123)	(0.108)	(0.165)	(0.139)	(0.129)	(0.156)
Toxic Fines on others	-0.043	-0.062	-0.088**	-0.060**	-0.063*	-0.035	-0.053
	(0.029)	(0.041)	(0.033)	(0.025)	(0.036)	(0.031)	(0.034)
R^2	0.08	0.12	0.11	0.07	0.10	0.07	0.11
Obs.	8,681	8,074	8,312	8,684	9,037	8,232	9,279

Panel B: Panel regressions, facility by year data, regulatory actions lagged two years

DEP.VAR: The log of:	As^	Cd	Cr	CN-^	Pb	Hg^	Ni
Toxic Inspections	-0.237	-0.477	-0.280	-0.462	-0.281	-0.168	-0.586***
	(0.291)	(0.305)	(0.309)	(0.293)	(0.260)	(0.255)	(0.207)
Non-toxic Insp.	-0.377	-0.930***	-0.893***	-0.404*	-0.338	-0.019	-0.488
	(0.256)	(0.291)	(0.301)	(0.236)	(0.300)	(0.290)	(0.380)
Toxic Violations	0.048	0.264***	0.135	0.189**	0.086	-0.000	0.180*
	(0.083)	(0.091)	(0.080)	(0.072)	(0.075)	(0.087)	(0.093)
Non-toxic Viol.	0.307**	0.718***	0.654***	0.455**	0.397**	0.236	0.533**
	(0.146)	(0.156)	(0.183)	(0.169)	(0.187)	(0.154)	(0.241)
Toxic Inspections on others	-0.000	-0.001	-0.000	-0.001	-0.004	-0.001	-0.006
	(0.004)	(0.008)	(0.009)	(0.005)	(0.006)	(0.004)	(0.007)
Toxic Fines	0.044	-0.030	-0.004	0.014	0.024	0.063	0.127
	(0.093)	(0.114)	(0.110)	(0.108)	(0.090)	(0.100)	(0.121)
Non-toxic Fines	0.063	-0.113	-0.082	-0.099	-0.144	-0.098	-0.219
	(0.090)	(0.137)	(0.132)	(0.175)	(0.161)	(0.141)	(0.168)
Toxic Fines on others	-0.055**	-0.077**	-0.102***	-0.060**	-0.051*	-0.014	-0.062**
	(0.026)	(0.036)	(0.026)	(0.027)	(0.027)	(0.035)	(0.029)
R^2	0.08	0.13	0.11	0.07	0.10	0.07	0.11
Obs.	8,681	8,074	8,312	8,684	9,037	8,232	9,279

NOTES: Standard errors clustered at state level in parentheses; *** p<0.01, ** p<0.05, * p<0.1. ^ denotes results do not include the years 2014 and 2015 for arsenic, cyanide, and mercury.

5. DISCUSSION AND CONCLUSION

In this paper, we highlight specific mechanisms through which environmental regulation in Mexico is effective despite being limited in scope and function. We find positive evidence on cost-efficiency in targeting polluters with a prior history of significant non-compliance. If a plant had one more violation under toxic inspection, its chance of inspections rises by 1%. We identify additional synergies of specific targeting by utilizing outcomes from all other inspection programs on the plant. One more violation under all other programs increases its probability of toxic inspections by 1-2%.

We find positive evidence of fines imposed for severe violations under the toxic inspection program. One more past violation under toxic inspections raises the probability of being fined by 3-4%. The amount fined on the plant is also proportional to the severity of non-compliance under the toxic inspection program. One more priority violation for toxic inspections on itself results in an increase in the amount fined by 1%.

We find positive evidence of increased monitoring activities in the same jurisdiction leading to increased activities directed against the individual plant. One more inspection visit on all other plants in the same municipality results in a higher probability of inspections for the plant itself by 0.1%. Higher inspections on others also result in a higher probability of being fined by less than 0.1% and a higher fined amount on the plant itself by 0.1%. The underlying mechanism is that higher regulatory activities, in general, imply increased monitoring of the plant itself, leading to the detection of potential reporting protocol failures and an increase in the amount fined.

We find weak evidence of regulators targeting plants located in poorer or marginalized communities. The proportion of the population between 6 and 14 years old that do not attend school and the proportion of households without washing machines are linked to increased inspections for three to five pollutants depending on the time lag on regulatory variables.

We find positive evidence of the effectiveness of recent enforcement actions because past violations detected as an outcome of inspection visits lead to an increase in self-reported pollution levels. One more priority violation under the toxic program leads to increased self-reported discharges by almost 0.20% (statistically significant for three pollutants). Plants are subject to multiple inspection programs simultaneously that might explain the larger magnitude of violations under other programs leading to an increase in self-reported discharges by around 0.2-0.6%. We conclude that traditional regulatory pressure effectively improves self-reporting practices by detecting violations in protocols and more accurate or up-to-date measurements.

Last, we find evidence on the deterrence effect of general regulator reputation. Results show that a 1% increase in amount fined on other facilities in the same municipality results in a reduction in annual chromium discharges by 0.07-0.10%, cadmium discharges by 0.06-0.08%, lead discharges by 0.05-0.07%, and cyanide discharges by 0.05-0.06%. For the remaining three toxics, the coefficient on lagged fined amount on others is consistently negative but not always significant at conventional levels (nickel 0.03-0.06%, arsenic 0.02-0.06%, and mercury 0.01-0.04%). Shimshack and Ward (2005) find evidence on significant regulator reputation effects in the US. Preliminary findings from developing countries show that general deterrence effects like more visible enforcement actions of plant closures affect plant-level pollution than specific deterrence effects (Caffera and Lagomarsino 2014). In Mexico, the imposition of fines by PROFEPA is widely publicized in the news media, as cited in the introduction.

REFERENCES

Alvarez-Larrauri, R. & Fogel, I. (2008). Environmental audits as a policy of state: 10 years of experience in Mexico. *Journal of Cleaner Production*, 16(1):66-74.

Blackman, A. (2012). Does eco-certification boost regulatory compliance in developing countries? ISO 14001 in Mexico. *Journal of Regulatory Economics*, 42:242–263.

Blackman, A. (2010). Alternative Pollution Control Policies in Developing Countries. *Review of Environmental Economics and Policy*, vol. 4(2), pages 234-253, Summer.

Blackman, A., Lahiri, B., Pizer, B., Rivera Planter, M., & Muñoz Piña, C. (2010). Voluntary regulation in developing countries: Mexico's clean industry program. *Journal of Environmental Economics and Management*, 60(3), 182–192.

Briceno, S., & Chávez, C. (2010). *Determinantes de cumplimiento en el programa de tasas retributivas en Colombia. El caso de Corpochivor*. *El Trimestre Economico*, Vol. 77, *Núm.* 308.

Caffera, M. & Lagomarsino, A. (2014). Under reporting of water pollution by industrial plants: empirical evidence. *Latin American and Caribbean Environmental Economics Program LACEEP Working Paper Series*, WP66.

Camacho, G. M. O. (2016). *La capacidad potencial de influencia del sector industrial manufacturer Un análisis del Programa de Inspección y Vigilancia Industrial en México*. *Gestión y Política Pública*, *VOLUMEN* XXV . *NÚMERO* 1 . I *SEMESTRE DE* 2016 . pp. 33-79.

CEC, Commission for Environmental Cooperation (2018). *Taking Stock: North American Pollutant Releases and Transfers*, *Vol. 15.* Montreal, Canada: Commission for Environmental Cooperation. 154 pp.

CEC, Commission for Environmental Cooperation (Montréal, Québec). (2011). *Taking Stock: North American Pollutant Releases and Transfers Vol. 13*. March 2011.

Chakraborti, L. & Shimshack J.P. (2020). Environmental disparities in the Global South: Evidence from toxic water pollution in urban Mexico. *University of Virginia Working Paper,* June 2020.

Challenger, A., Cordova, A., Lazos Chavero, E., Equihua, M. & Maass., M. (2018). Opportunities and obstacles to socioecosystem-based environmental policy in Mexico: expert opinion at the science-policy interface. *Ecology and Society*, 23(2):31. https://doi.org/10.5751/ES-10066-230231.

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

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

Escobar, N. & Chavez, C. (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.

Gray, W. B., & Shadbegian, R. J. (2004). 'Optimal' pollution abatement—whose benefits matter, and how much? *Journal of Environmental Economics and Management*, 47(3), 510-534.

Gray, W. B. & Shimshack, J. P. (2011). The Effectiveness of Environmental Monitoring and Enforcement: A Review of the Empirical Evidence. *Review of Environmental Economics and Policy*, 5(1):3-24.

Gupta, S., Saksena, S. & Baris, O. (2019). Environmental enforcement and compliance in developing countries: Evidence from India. *World Development* 117 (2019) 313–327.

Helland, E. (1998). The Enforcement of Pollution Control Laws: Inspections, Violations, and Self-Reporting. *Review of Economics and Statistics* 80 (1):141-53.

Lin, L. (2013). Enforcement of pollution levies in China. *Journal of Public Economics*, vol. 98(C), pages 32-43.

Palacios, M., & Chávez, C. (2005). Determinants of compliance in the emissions compensation program in Santiago, Chile. *Environment and Development Economics*, 10(4): 453–83.

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.

PROFEPA. (2013). *Guía de Autoevaluación Ambiental*, *Procuraduría Federal de Protección al Ambiente*, Date published 12th April, 2013.

Saha, S. & Mohr, R.D. (2013). Media attention and the Toxics Release Inventory. *Ecological Economics,* 93:284–291.

Shimshack, J. P. (2014). The Economics of Environmental Monitoring and Enforcement: A Review. *Annual Review of Resource Economics*, 6: 339–60.

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

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

APPENDIX:

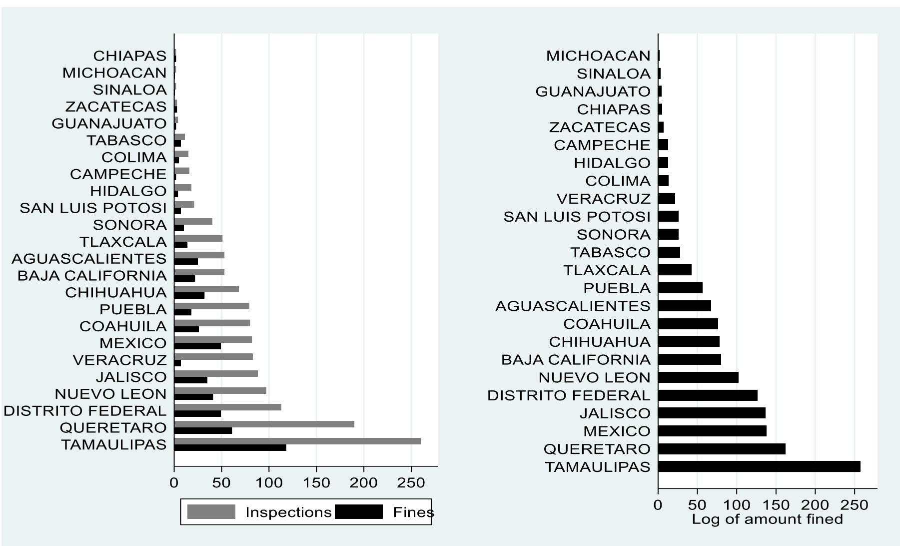
1. Data Appendix

2. Regular and Verification Inspections Appendix

3. Missing Pollution Reports Appendix

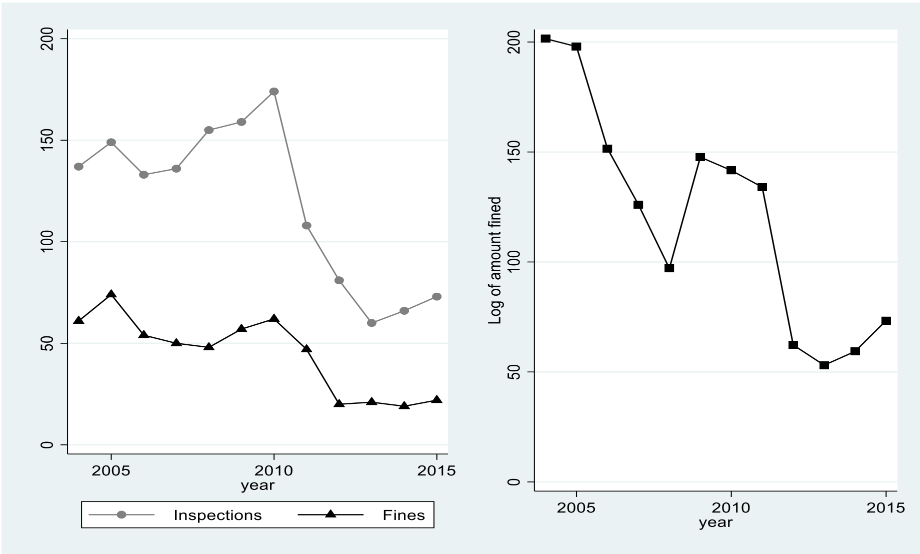
1. Data Appendix

In this Appendix, we describe regulatory activities in more detail. Appendix Figure 1 presents the statewide distribution of regulatory activities of toxic inspections, fines, and log of amount fined in real USD. We observe that inspections and fines were higher in Tamaulipas (Northeast industrial corridor), Queretaro, Distrito Federal (Mexico City), Nuevo Leon, and Jalisco (the last three states include the largest metropolitan cities of Mexico). The second panel shows that the log of amount fined under toxic inspections was highest in Tamaulipas, Queretaro, Jalisco, State of Mexico (Mexico in the bar chart), and Distrito Federal (Mexico City).



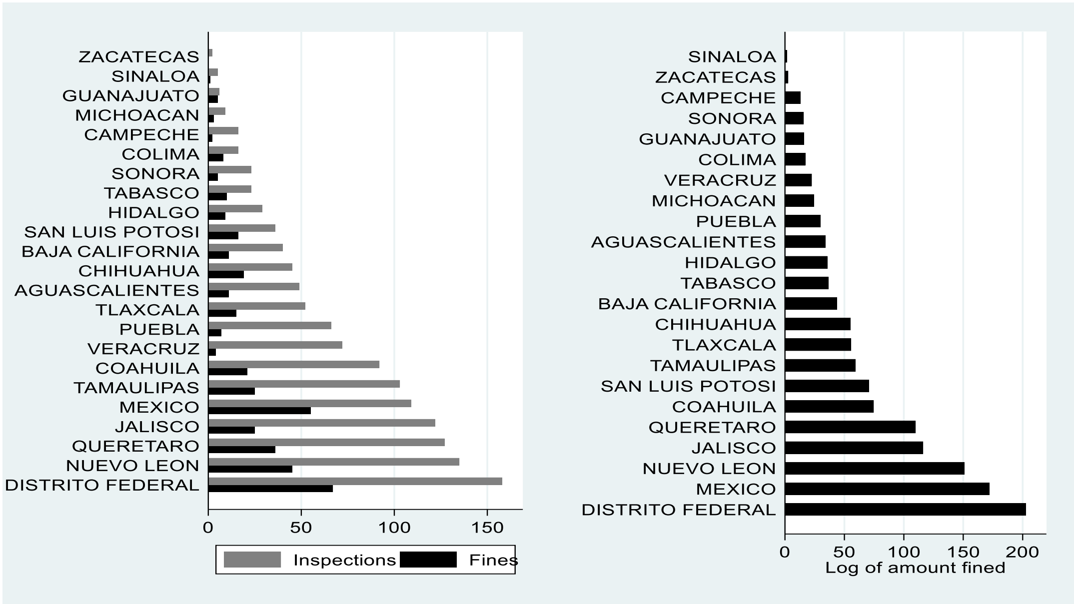
Appendix Figure 1. Distribution of the total number of toxic inspections, fines imposed, and log of amount fined by states, 2004-2015.

Appendix Figure 2 presents trends in the annual data for the total number of toxic inspections, fines imposed, and log of amount fined. From 2004 to 2015, all three indicators of regulatory activities exhibit a declining trend with a peak in inspections in 2010. The second panel shows that the log of amount fined declined from 2004 to 2015, with some increase in fines in 2009-2010.



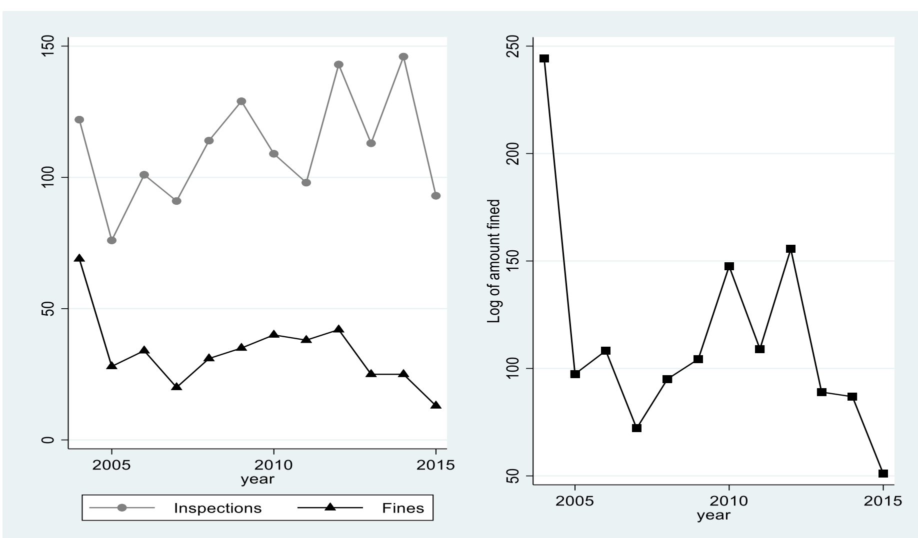
Appendix Figure 2. Trends in the total number of toxic inspections, fines imposed, and log of amount fined, over 2004-2015.

Appendix Figure 3 presents the statewide distribution of regulatory activities under non-toxic (all other programs) inspections, fines, and log of amount fined in real USD. The total count of inspections and fines was highest in Distrito Federal (Mexico City), Nuevo Leon, Queretaro, Jalisco, and State of Mexico (Mexico in the bar chart). The second panel shows that the log of amount fined under all other (non-toxic) inspections was highest in Distrito Federal (Mexico City), State of Mexico (Mexico in the bar chart), Nuevo Leon, Jalisco, and Queretaro.



Appendix Figure 3. Distribution of the total number of non-toxic inspections, fines imposed, and log of amount fined by states, 2004-2015.

Appendix Figure 4 presents trends in the annual data for the total number of non-toxic inspections, fines imposed, and log of amount fined. The total number of non-toxic inspections was on a slight upward trend. The total number of fines imposed under non-toxic programs and the sum of logged amount fined (second panel) do not exhibit a significant trend from 2004.



Appendix Figure 4. Trends in the total number of non-toxic inspections, fines imposed, and log of amount fined, over 2004-2015.

Appendix Table 1 presents summary statistics on all non-toxic programs. A plant got inspected 0.05 times annually under all non-toxic inspection programs. On average, a plant faced a financial penalty only 0.01 times in a year under all non-toxic inspection programs. Of the positive fined amounts, on average, a plant faced a penalty of $256 for positive fines under all other non-toxic programs. In the past three (two) years, a plant was likely to be inspected 0.13 (0.09) times and fined 0.05 (0.03) times with an average fine of $274 ($268) for positive fines. In the past three (two) years, inspections, fines and amount fined faced by other plants in the same municipality was 9.58 (3.91) times, 4.45 (1.67) times, and average fined amount of $699 ($586) for positive fines.

Appendix Table 1. Summary Statistics on non-toxic regulatory activities

Variables	Obs.	Mean	Std. Dev.	Max.
INSPECTIONS, NON-TOXICS				
Annual inspections on itself (#)	11,860	0.05	0.21	1.00
Past 3 yr. inspections on itself (#)	11,860	0.13	0.42	3.00
Past 3 yr. inspections on others (#)	11,860	9.58	30.06	171.00
Past 2 yr. inspections on itself (#)	11,860	0.09	0.32	2.00
Past 2 yr. inspections on others (#)	11,860	3.91	13.53	90.00
FINES IMPOSED, NON-TOXICS				
Annual fines on itself (#)	11,860	0.01	0.12	1.00
Past 3 yr. fines on itself (#)	11,860	0.05	0.23	3.00
Past 3 yr. fines on others (#)	11,860	4.45	15.33	88.00
Past 2 yr. fines on itself (#)	11,860	0.03	0.19	2.00
Past 2 yr. fines on others (#)	11,860	1.67	6.72	45.00
AMOUNT FINED, NON-TOXICS				
Annual fines on itself (2010 USD)	11,860	3.91	248.32	22789.46
Annual fines on itself, given fines>0	181	256.11	1999.41	22789.46
Past 3 yr. fines on itself (2010 USD)	11,860	10.41	393.88	22789.46
Past 3 yr. fines on itself, given fines>0	451	273.63	2004.07	22789.46
Past 3 yr. fines on others (2010 USD)	11,860	269.90	2208.05	28294.75
Past 3 yr. fines on others, given fines>0	4,579	699.07	3511.35	28294.75
Past 2 yr. fines on itself (2010 USD)	11,860	7.61	332.53	22789.46
Past 2 yr. fines on itself, given fines>0	337	267.80	1957.76	22789.46
Past 2 yr. fines on others (2010 USD)	11,860	190.22	1837.13	23188.77
Past 2 yr. fines on others, given fines>0	3,850	585.97	3188.54	23188.77

NOTES: The summary statistics are for 3,432 facilities across Mexico.

2. Regular and Verification Inspections Appendix

In this section, we differentiate between regular and verification inspections by estimating separate models. The primary objective is to identify whether regular visits have distinct determinants from verification visits. For example, if initial visits, part of regular monitoring protocol, is higher for plants that belong to high-risk, environmental impacts or toxics residuals industrial sectors, and verification visits depend on the outcome of the initial inspection visit.

Overall, for initial visits, we find evidence of targeting based on the type of manufacturing facility as regular inspections conducted on the plant during the past three (two) years are significant determinants of inspections (Appendix Table 2 and Appendix Table 3). The shorter time lag of the past two years is significant in predicting current inspections for the toxic program (2 percentage points). However, for both time lags, past inspections under all other non-toxic programs significantly determine current toxic inspections by almost three percentage points (significant for all seven toxics). If the plant had verification visits under either toxic and all other inspections programs, it was likely to be targeted for regular inspections (between 2 and 3 percentage points). Complaints by citizens and emergencies (denoted by comp. in the tables) filed in the past two years lead to higher current inspections between 1 and 4 percentage points (significant for cyanide, lead, and mercury). Higher toxic inspections on all other plants in the same municipality and higher fined amounts under toxic inspection programs on all other plants in the same municipality lead to a higher likelihood of current inspections. Coefficients are statistically significant for the past two years measures. Past violations (and higher fined amount on itself for past three years lag) is negative; that is counterintuitive. However, results presented in Appendix Table 4 and Appendix Table 5 show that priority violations for both toxic and non-toxic programs (and higher fined amounts for the past three years lag) are significant determinants of verification visits.

The coefficients on socioeconomic variables are rarely significant. For initial visits, we find that polluters located in denser municipalities are visited less due to limited regulatory resources to conduct monitoring activities of high concentration of manufacturing and might be related to local factors such as a larger agglomeration of industries implying fewer regular visits of major polluting plants. The other two socioeconomic status variables (proportion of the population between 6 and 14 years old that do not attend school and proportion of households without a washing machine) maintain sign and significance with plants located in municipalities with higher shares inspected more.

Appendix Table 2. Regular Inspection Models (lagged values over the past three years)

Panel A: RE Probit Regular Inspections, Marginal effects at mean values, lagged values over the past three years							
DEP.VAR: Regular inspections:	As^	Cd	Cr	CN-^	Pb	Hg^	Ni
reg. tox insp.	0.023*	0.024*	0.023	0.014	0.020	0.022	0.019
	(0.014)	(0.014)	(0.015)	(0.014)	(0.014)	(0.014)	(0.015)
reg. n-tox insp.	0.027***	0.026***	0.026***	0.029***	0.027***	0.019***	0.023***
	(0.007)	(0.010)	(0.008)	(0.008)	(0.009)	(0.007)	(0.007)
comp. tox insp.	0.025*	0.0086	0.002	0.021	0.015	0.017	0.007
	(0.013)	(0.017)	(0.015)	(0.017)	(0.016)	(0.014)	(0.021)
comp. n-tox	0.016	0.013	0.009	0.011	0.015	0.003	0.011
insp.	(0.011)	(0.014)	(0.017)	(0.015)	(0.013)	(0.015)	(0.013)
ver. tox insp.	0.021***	0.016**	0.017**	0.016**	0.013	0.019**	0.012
	(0.007)	(0.008)	(0.008)	(0.007)	(0.008)	(0.007)	(0.009)
ver. n-tox insp.	0.024***	0.025**	0.024***	0.025***	0.026***	0.018*	0.017**
	(0.008)	(0.011)	(0.009)	(0.009)	(0.010)	(0.009)	(0.008)
past tox viol.	-0.004	0.001	0.000	-0.002	0.001	-0.003	0.001
	(0.005)	(0.007)	(0.006)	(0.006)	(0.007)	(0.006)	(0.007)
past n-tox viol.	-0.007**	-0.007*	-0.008*	-0.010**	-0.007**	-0.004	-0.006**
	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)
reg. tox insp.	0.000	0.000*	0.000	0.000	0.000	0.000	0.000
others	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ver. tox insp.	-0.000	-0.001	-0.001	-0.000	-0.001	-0.001	-0.001
others	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)
comp. tox insp.	0.000	0.002	0.001	0.000	0.001	0.002	0.002
others	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
past tox fines	-0.002	-0.005*	-0.004	-0.003	-0.004*	-0.002	-0.005*
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
past n-tox fines	-0.001	-0.002	-0.000	0.000	-0.002	-0.001	-0.000
	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)
past tox fines	0.001	0.001*	0.001	0.001	0.001	0.002**	0.001
others	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Obs.	8,681	8,074	8,312	8,684	9,037	8,232	9,279

NOTES: Standard errors clustered at state level in parentheses; *** p<0.01, ** p<0.05, * p<0.1. ^ denotes results do not include the years 2014 and 2015 for arsenic, cyanide, and mercury.

Appendix Table 3. Regular Inspection Models (lagged values over the past two years)

Panel A: RE Probit Regular Inspections, Marginal effects at mean values, lagged values over the past two years

DEP.VAR: Regular inspections:	As^	Cd	Cr	CN-^	Pb	Hg^	Ni
reg. tox insp.	0.026*	0.027**	0.026*	0.021	0.019	0.026*	0.017
	(0.015)	(0.013)	(0.015)	(0.013)	(0.014)	(0.014)	(0.017)
reg. n-tox insp.	0.025***	0.031***	0.030***	0.025**	0.028***	0.015**	0.019**
	(0.008)	(0.010)	(0.011)	(0.009)	(0.009)	(0.006)	(0.009)
comp. tox insp.	0.033	0.014	0.003	0.043**	0.028*	0.033*	0.023
	(0.020)	(0.021)	(0.025)	(0.019)	(0.017)	(0.018)	(0.016)
comp. n-tox insp.	0.018	0.023	0.022	0.014	0.022	0.013	0.006
	(0.013)	(0.016)	(0.019)	(0.017)	(0.015)	(0.016)	(0.014)
ver. tox insp.	0.032***	0.027***	0.032***	0.032***	0.025***	0.031***	0.021**
	(0.008)	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)	(0.009)
ver. n-tox insp.	0.021**	0.032***	0.027**	0.020*	0.030***	0.016	0.015
	(0.009)	(0.011)	(0.010)	(0.011)	(0.011)	(0.010)	(0.010)
past tox viol.	-0.012**	-0.007	-0.009	-0.013***	-0.007	-0.013**	-0.006
	(0.005)	(0.005)	(0.006)	(0.005)	(0.005)	(0.005)	(0.006)
past n-tox viol.	-0.006	-0.008*	-0.007	-0.008*	-0.007	-0.002	-0.003
	(0.004)	(0.004)	(0.006)	(0.005)	(0.004)	(0.004)	(0.004)
reg. tox insp. others	0.000	0.001**	0.001**	0.000*	0.000	0.000	0.001*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ver. tox insp. others	-0.001	-0.002*	-0.002*	0.000	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
comp. tox insp. others	0.001	0.004*	0.001	-0.000	0.003	0.003	0.002
	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)
past tox fines	0.001	-0.000	-0.000	0.001	-0.000	0.002	-0.002
	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
past n-tox fines	0.000	-0.002	-0.000	0.002	-0.003	0.001	0.000
	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)
past tox fines others	0.002*	0.001*	0.002**	0.002*	0.002**	0.002**	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Obs.	8,681	8,074	8,312	8,684	9,037	8,232	9,279

NOTES: Standard errors clustered at state level in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$. ^ denotes results do not include the years 2014 and 2015 for arsenic, cyanide, and mercury.

Appendix Table 4. Verification Inspection Models (lagged values over the past three years)

Panel A: Verification Inspections, Marginal effects at mean values, lagged values over the past three years							
DEP.VAR: Verification inspections:	As^	Cd	Cr	CN-^	Pb	Hg^	Ni
reg. tox insp.	-0.006	-0.008*	-0.007*	-0.005	-0.005*	-0.005	-0.006
	(0.004)	(0.005)	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)
reg. n-tox insp.	-0.001	-0.001	0.004	-0.001	-0.000	-0.004	0.002
	(0.005)	(0.005)	(0.003)	(0.004)	(0.002)	(0.004)	(0.002)
comp. tox insp.	-0.006	-0.006	-0.009*	-0.007	-0.006	-0.007	-0.005
	(0.006)	(0.005)	(0.005)	(0.006)	(0.004)	(0.005)	(0.004)
comp. n-tox insp.	-0.003	-0.002	0.008	-0.003	-0.001	-0.007	0.001
	(0.007)	(0.006)	(0.005)	(0.006)	(0.004)	(0.006)	(0.004)
ver. tox insp.	-0.009**	-0.010*	-0.011*	-0.010*	-0.010*	-0.008*	-0.011*
	(0.004)	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)	(0.006)
ver. n-tox insp.	-0.004	-0.003	0.001	-0.005*	-0.004	-0.007**	-0.001
	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)	(0.002)
past tox viol.	0.008***	0.008***	0.008***	0.008**	0.007***	0.008**	0.007**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
past n-tox viol.	0.003	0.003*	-0.000	0.003*	0.003**	0.004**	0.002
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
reg. tox insp. others	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ver. tox insp. others	-0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
comp. tox insp. others	0.000	0.000	-0.001	-0.000	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
past tox fines	0.001	0.002*	0.002**	0.002	0.002*	0.001	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
past n-tox fines	0.001	0.001	0.001	0.001	0.000	0.001	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
past tox fines others	0.001	0.000	0.000	0.000	0.001*	0.000	0.000
	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)
Obs.	8,681	8,074	8,312	8,684	9,037	8,232	9,279

NOTES: Standard errors clustered at state level in parentheses; *** p<0.01, ** p<0.05, * p<0.1. ^ denotes results do not include the years 2014 and 2015 for arsenic, cyanide, and mercury.

Appendix Table 5. Verification Inspection Models (lagged values over the past two years)

Panel A: Verification Inspections, Marginal effects at mean values, lagged values over the past two years

DEP.VAR: Verification inspections:	As^	Cd	Cr	CN-^	Pb	Hg^	Ni
reg. tox insp.	-0.004	-0.004	-0.004	-0.004	-0.003	-0.003	-0.003
	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)
reg. n-tox insp.	-0.005	-0.006	0.000	-0.003	-0.002	-0.006	-0.003
	(0.005)	(0.005)	(0.004)	(0.004)	(0.003)	(0.004)	(0.003)
comp. tox insp.	-0.004	-0.005	-0.008	-0.007	-0.004	-0.006	-0.003
	(0.007)	(0.007)	(0.007)	(0.008)	(0.006)	(0.007)	(0.005)
comp. n-tox	-0.007	-0.005	0.006	-0.003	-0.000	-0.009	-0.002
insp.	(0.009)	(0.008)	(0.006)	(0.007)	(0.004)	(0.008)	(0.006)
ver. tox insp.	-0.007	-0.005	-0.007	-0.007	-0.005	-0.005	-0.006
	(0.005)	(0.005)	(0.005)	(0.004)	(0.005)	(0.004)	(0.005)
ver. n-tox insp.	-0.004	-0.004	-0.000	-0.005	-0.002	-0.007*	-0.002
	(0.003)	(0.004)	(0.005)	(0.004)	(0.004)	(0.004)	(0.003)
past tox viol.	0.009***	0.008***	0.008***	0.009***	0.008***	0.009***	0.007**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
past n-tox viol.	0.004**	0.005**	0.002	0.004***	0.003**	0.005***	0.004**
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)
reg. tox insp.	-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000
others	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ver. tox insp.	0.000	0.001	0.001**	0.000	0.001	0.000	0.001*
others	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
comp. tox insp.	0.001	0.001	-0.002	-0.000	-0.001	-0.000	-0.002*
others	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
past tox fines	0.001	0.001	0.002*	0.001	0.001	0.000	0.001*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
past n-tox fines	0.002*	0.001	0.001	0.001	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
past tox fines	0.001	0.000	0.000	0.000	0.001*	0.000	0.000
others	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)
Obs.	8,681	8,074	8,312	8,684	9,037	8,232	9,279

NOTES: Standard errors clustered at state level in parentheses; *** p<0.01, ** p<0.05, * p<0.1. ^ denotes results do not include the years 2014 and 2015 for arsenic, cyanide, and mercury.

3. Missing Pollution Reports Appendix

In this Appendix, we address the unbalanced nature of the annual pollution data. We cannot confirm whether plants that do not report certain pollutants in some years are due to no discharge into water, or zero or below detectable standard for measurement equipment or intentional missing reports (due to no measurement). In Appendix Table 6, we predict the probability of missing reports based on the same explanatory variables as in the main pollution model. We find that increased number of past violations under toxic and non-toxic monitoring programs lead to a lower probability of missing reports for all seven pollutants. Increased fined amount in the past (on itself) under toxic program leads to a lower probability of missing reports for five out of the seven pollutants for the two years lagged measures (four out of the seven pollutants for the three years lagged measures). We infer that priority violations under toxic or all other monitoring programs and fines imposed under toxic inspections promote annual reporting, which means that specific enforcement actions effectively improve pollution measurement protocols at the plant. However, past inspection visits that do not result in serious violations has the opposite effect of increasing the probability of missing reports for six out of the seven pollutants for the two years lagged measures(three out of the seven pollutants for the three years lagged measures) which reflects limited inspector resources to visit all major plants each year. For the results focusing on non-missing pollution reports, no systematic bias arises as the monitoring and enforcement programs do not provide plants with under-reporting incentives.

Appendix Table 6. Pollution Report Missing Models

Panel A: RE Probit, Marginal effects at mean values, lagged values over the past three years

DEP.VAR: Report Missing:	As^	Cd	Cr	CN-^	Pb	Hg^	Ni
past tox insp.	0.022	0.033**	0.032**	0.020	0.027**	0.025	0.018
	(0.015)	(0.013)	(0.013)	(0.015)	(0.013)	(0.015)	(0.014)
past n-tox	-0.013	0.012	0.030*	-0.009	0.016	0.006	0.012
insp.	(0.019)	(0.016)	(0.016)	(0.018)	(0.016)	(0.019)	(0.016)
past tox viol.	-0.014*	-0.021***	-0.023***	-0.013*	-0.018***	-0.020***	-0.016**
	(0.008)	(0.006)	(0.007)	(0.008)	(0.007)	(0.008)	(0.007)
past n-tox	-0.024**	-0.030***	-0.041***	-0.024**	-0.032***	-0.028**	-0.029***
viol.	(0.011)	(0.010)	(0.010)	(0.011)	(0.010)	(0.011)	(0.010)
past tox insp.	-0.000***	-0.000	-0.000	-0.000**	-0.000**	-0.000*	-0.000**
others	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
past tox fines	-0.0101*	-0.009*	-0.007	-0.010*	-0.009*	-0.009	-0.005
	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)	(0.006)	(0.005)
past n-tox	-0.004	-0.004	-0.007	-0.010*	-0.006	-0.011*	-0.007
fines	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)	(0.006)	(0.005)
past tox fines	0.002	-0.001	-0.001	0.001	0.001	0.000	0.000
others	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Obs.	29,616	34,016	34,232	29,676	36,056	29,176	36,056

Panel B: RE Probit, Marginal effects at mean values, lagged values over the past two years

DEP.VAR: Report Missing:	As^	Cd	Cr	CN-^	Pb	Hg^	Ni
past tox insp.	0.044**	0.034**	0.027*	0.041**	0.029*	0.037**	0.015
	(0.018)	(0.016)	(0.016)	(0.018)	(0.016)	(0.018)	(0.016)
past n-tox	-0.011	0.014	0.031*	-0.001	0.008	-0.002	0.014
insp.	(0.021)	(0.019)	(0.019)	(0.021)	(0.019)	(0.021)	(0.019)
past tox viol.	-0.025***	-0.025***	-0.025***	-0.023***	-0.021***	-0.027***	-0.018**
	(0.009)	(0.007)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
past n-tox	-0.034***	-0.035***	-0.045***	-0.037***	-0.031***	-0.030**	-0.033***
viol.	(0.013)	(0.011)	(0.011)	(0.013)	(0.01)	(0.013)	(0.012)
past tox insp.	-0.000	0.000	0.000	-0.000	-0.000	-0.000	-0.000
others	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
past tox fines	-0.014**	-0.011**	-0.008	-0.016**	-0.013**	-0.015**	-0.007
	(0.007)	(0.006)	(0.006)	(0.007)	(0.006)	(0.007)	(0.006)
past n-tox	0.003	-0.002	-0.005	-0.006	-0.003	-0.003	-0.005
fines	(0.007)	(0.006)	(0.006)	(0.007)	(0.006)	(0.007)	(0.006)
past tox fines	-0.001	-0.002	-0.003	-0.002	-0.001	-0.003	-0.001
others	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Obs.	29,616	34,016	34,232	29,676	36,056	29,176	36,056

NOTES: Standard errors clustered at state level in parentheses; *** p<0.01, ** p<0.05, * p<0.1. ^ denotes results do not include the years 2014 and 2015 for arsenic, cyanide, and mercury.