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# Do industries pollute more in poorer neighborhoods? Evidence from toxic releasing plants in Mexico

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## Abstract

This paper provides evidence that poorer communities in Mexico are associated with higher toxics pollution releases. We utilize previously unused, self-reported, plant-level annual databases (2004 to 2012) and the Urban Marginalization Index (IMU for its Spanish acronym) published by Mexican government's National Population Council (2000, 2005 and 2010). We cover seven toxic pollutants (arsenic, cadmium, chromium, cyanide, lead, mercury and nickel) that are most frequently reported and have significant negative health impacts on the affected population. We conduct the analysis at the local level of AGEBs (Área Geoestadística Básica Urbana) that are roughly comparable to census tracts in the US, but only for urban areas. We find that the burden of pollution is disproportionately borne by less prosperous communities in Mexico, although the difference is not always statistically significant. From our most recent and most reliable cross-section, the coefficients indicate that a plant with a one-unit higher IMU is predicted to emit about 87% more cyanide, 72% more arsenic and chromium and 57% more nickel, than one in the average community. The quantile regressions show that this positive relationship between marginalization and pollution can be mostly explained by the response of plants at the higher end of the pollution distribution, as the coefficients are always positive and statistically significant for the higher percentile regressions.

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## 1. Introduction

In rich countries, a large body of evidence shows that emissions of dangerous and noxious pollutants are generally greater in poorer regions. This is the pattern expected to emerge if those communities are politically weak (the "environmental justice" perspective) or if prosperous families eschew polluted environments so that the local communities end up poorer (the "compensating differentials" or "sorting" perspective).[1] Evidence from less developed countries is rather sparse, but the general conclusion has been nearly the opposite. As summarized by Grineski et al. (2015), "it is generally economically better-off residents who are exposed to greater densities of industrial hazards… This has been posited to relate to urban development trajectories that are fundamentally different in the Global South, where elites are more likely to inhabit the urban core where they can take advantage of its paved roads and relatively developed civil infrastructure, among other benefits, while the most socially marginalized reside in informally developed peri-urban areas (p. 1-2)."

Most of the studies behind that conclusion deal with Mexico. What they measure is not pollution exposure *per se*, but the density of industrial activity thought likely to be the source of pollution. The perception that elites suffer greater exposure may be quite deceptive if it is the case that those industries in poorer communities pollute more.

In this paper, we present evidence that this is the case for an important category of emissions. Among urban plants in Mexico that emit any of seven toxic metals into the water, those surrounded by poor people emit substantially more, although the difference is not always statistically significant. For example, in our most recent and most reliable cross section, a plant with an Urban Marginalization Index (IMU for its Spanish acronym) one unit higher is predicted to emit about 87% more cyanide, 72% more arsenic and chromium, and 57% more nickel, than one in the average community. The smallest association measured in that cross section, which is not statistically significant, is 35% more cadmium discharged into water for a one-unit increase in the marginalization index. Estimates from the early periods are somewhat smaller but not enough to speak with confidence of an increase over time. From the earliest data, around 2004, the associations are large enough to constitute a major caveat to the emerging picture of elite exposure. In addition, for plants that are emitting at higher quantiles of the distribution, the magnitude of this relationship becomes stronger.

[1] Evidence favoring the view that demographics cause pollution includes Viscusi and Hamilton's (1999) finding that Superfund sites near politically active communities get more ambitious clean-up targets. Similarly, Gray and Shadbegian (2004) find that plants in areas with politically active populations that are also environmentally conscious emit less pollution. Favoring the opposite causal direction, Currie et al. (2015), find housing values fall after plants releasing toxic pollutants open within a distance (1/2 to 1 mile) believed to correspond to how far the pollutants travel.

We report on disposal into water and on these seven toxic metals because that is the subject of a larger project still in its preliminary stages. Thus, this is not an observation plucked from the several hundred substances-medium combinations we may be able to examine in the coming years; rather, it deals with the only pollution flows we have examined with enough care to draw any conclusions at all. The aim of the larger project is to measure the responsiveness of firms to characteristics of surrounding population, which will require data on confounding variables and possible instruments as well as some calculations to allow comparison of the data used here across time periods. As this is likely to take a couple of years, we hasten to bring these preliminary results to the attention of those aware of the previously reported associations between class and exposure.

Our confidence in that observation is bolstered by several other ways of looking at the data and alternative statistical treatments that relax the (log) linearity assumption and focus on the cases of zero-emissions.[2] The results we present here were chosen because they involve a minimum of subtle researcher judgment: Essentially, they are bivariate regressions of emissions on a standard measure of economic deprivation published by the Mexican government.

## 2. Prior Literature

That poorer communities are exposed to more pollution in wealthy countries is confirmed by a very large body of research, often referred to as the environmental justice literature.[3] Most of the empirical literature stemmed from Hamilton's (1995) classification of discrimination based on gender, economic vulnerability, and willingness to engage in collective action. The predicted correlation has been found in many studies of the United States (Brooks and Sethi (1997) on air emissions; Arora and Cason (1998) on aggregate emissions; Helland and Whitford (2003) on emissions into air, water, and land treated separately), although not in all (Gray et al. 2012).

The basis for claiming a contrary pattern in poor countries is much smaller. To our knowledge, only such study measuring pollution directly, Dasgupta et al. (2002), found higher particulate matter emissions in higher-wage, urban municipalities in Brazil. Other country-wide work suggests that the kind of political pressure that can lead to greater pollution control in rich regions may be weak in Latin America: A 1995 confidential survey of 236 major polluters in Mexico found only about a fourth consider pressure from the neighboring community a significant factor in environmental decisions (Dasgupta et al. 2000).

Most of the other supporting evidence comes from US-Mexico border regions. The earliest of these was a study of *maquiladoras* (manufacturing plants which can import components and export assembled goods under special trade rules) in Ciudad Juárez, Chihuahua, across the border from El Paso, Texas (Blackman et al. 2004). Emissions were approximated by industry

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[2] Those results can be found in a working paper (http://cide.edu/repec/economia/pdf/DTE597.pdf).

[3] Mohai et al. (2009) summarize the first several decades of this work.

averages and supplemented by the informal reputation of two *maquiladora* plants as heavy polluters. The relevant finding is a null result: The poor did not suffer disproportionate exposure to air polluted by small particulate matter from these sources.

Lara-Valencia et al. (2009) first make the stronger claim in their study of Nogales, Sonora, also on the border but not across from a major US city. They defined a hazard zone as the area within one kilometer of an industrial plant and found that the populations of those zones were more educated and affluent than those elsewhere in the city. Grineski and Collins (2010) added to this evidence in another study of Ciudad Juárez. The authors find that more marginal communities defined by mean education or if population included more migrants, were farther from the *maquiladoras*. Grineski and Collins (2008) find that lower class neighborhoods were closer to *maquiladoras*, when conditioning on a measure of formal development. Finally, Grineski et al. (2015) show the density of industrial parks is positively correlated with indicators of social class in Tijuana, Baja California (south of San Diego). Social class in this case means higher mean education levels and formal residential development, measured through a principal component analysis using houses without mud floors, electricity, piped water, sewage infrastructure, refrigerator, and washing machine.

The social distribution of water pollution burdens, the subject of this study, does not seem to have been studied much even in the developed world. In Mexico, Frey (2003) discusses how industrial activities of the *maquiladoras* have exacerbated the border cities' water woes (both access and quality). Largely untreated industrial waste water containing substantial amounts of hazardous wastes (including heavy metals such as chromium, lead, and nickel) is discharged into surface waters affecting neighboring communities (Davis and Perez 1989; ITESM and InfoMexus 2002; Sanchez 1990; Varady el al. 2001; and Williams and Homedes 2001). However, other than anecdotal evidence, we could not find an explicit empirical investigation on environmental justice associated with the water pollution generated by these industries.

As noted in the introduction, most of the environmental justice literature in Mexico is about proximity to production facilities. Only Blackman et al. (2004) address actual emissions, and they stop well short of plant-level measurements. It is also all about the border region. What we present below deals with two complementary dimensions of the subject: Emissions per plant, as opposed to plants per person; and the nation as whole, rather than the border. Expanding the scope of the study to include the entire nation is especially relevant due to the industrial process in Mexico after the 1990s. Large industrial hubs developed in the capital city and surrounding states (largely facilitated by improvements in infrastructure) in addition to notable metropolitan cities like Monterrey (in the Northeast) and Guadalajara (in the West).

## 3. Data

The emissions data originate in a 2001 amendment to Mexico's General Law of Ecological Equilibrium and Environmental Protection (*Ley General de Equilibrio Ecológico y Protección al Ambiente*) and a rulemaking process over the subsequent years. As of June 2004, virtually all entities that make use of more than small amounts of toxic substances (104 are listed) need to report how much of each substance ends up where (i.e., discharged into land, water or air, or sent to recycling facilities). More precisely, the requirement applies to any facility that handles hazardous waste or discharges pollutants into national water bodies, and to any firm in the 11 industrial sectors responsible for most pollution, if either its total use or total discharge exceeds a threshold established for each substance.[4]

The Mexican Secretariat for the Environment and Natural Resources *(Secretaria de Medio Ambiente y Recursos Naturales,* or SEMARNAT) compiles data from these reports into the Pollutant Release and Transfer Register (*Registro de Emisiones y Transferencias de Contaminantes*, or RETC) which has been available to the public online since 2006.

The size of the RETC database nearly doubled in its first decade, from 1,714 establishments in 2004 to 3,529 in 2013 (SEMARNAT 2013). This probably represents a failure to elicit compliance in the early years, as there was nothing close to a doubling in the size of the covered industries. Some establishments own several plants, and our data set (in which the plant is the unit of observation) actually shrinks over time. It seems likely, however, that the later cross sections are more representative. In addition to the inherent implausibility of so many new establishments coming into being, this judgment is suggested by other expert opinion. For example, the Commission for Environmental Cooperation of North America (CEC), an intergovernmental agency established in a side accord with the 1994 North American Free Trade Agreement, judges it likely that many plants had not yet installed pollution measurement equipment or trained personnel in the early years (CEC 2014).

Our project covers seven pollutants that are fairly common (among the top 25 pollutants for on-site water releases, in Mexico[5]) and pose some of the greatest threats to health from exposure (CEC 2009): Arsenic, cadmium, chromium, lead, mercury, and nickel, together with their compounds, and cyanide (organic and inorganic). Except for cyanide, firms are required to report on these if the total amount manufactured, processed, or otherwise used exceeds 5 kg per year, or the amount emitted exceeds 1 kg. For cyanide, the thresholds are 2500 kg used or 100 kg emitted. Most of the annual pollution reports are actually below the emissions thresholds. According to the CEC (2014), most of these facilities report their releases because the production threshold is binding.

We have reason to suspect substantial inaccuracy in these reports. Again, this is reflected in the views of other experts. Simple reporting errors appear to be common. According to a SEMARNAT official, these include "errors in the conversion of units and errors in the selection

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

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

of the appropriate substance for report (substances with similar names are often interchanged)" (Eicker et al. 2010, pp. 11-12). In addition, information on method used to report annual pollution levels is not publicly available. On top of this, we have found some cases of very improbable consistency: About a quarter of the pollution reports have duplicates at the same plant out to five or six significant digits, either for other metals or other years. Much of this plausibly corresponds to the precision of monitoring devices, but there are cases (such as 161.8841 kg of lead for the years 2010 and 2011) which can hardly be interpreted as anything other than failure to take new measurements.

For this reason, we are not making use of the full annual frequency of data. Instead, we work with three-year averages, which appears enough to reduce greatly the influence of erroneous reports and leave us with meaningful variation (see Table I).

Our decision to study discharges into water was originally guided by a belief that the affected population is more reliably people nearby than is the case for air or land emissions. These data also appear to be more complete than other aspects of these reports. (In contrast to water, most of the land emissions data are from after 2010.)

Each of the cross sections characterized in this paper consists of the plants which reported positive emissions into water of the metal under consideration and were within one kilometer of a measured Urban Marginalization Index (IMU). The IMU is measured at the geographic level known as the AGEB (*Área Geoestadística Básica Urbana*), which is roughly comparable to an urban census tract in the United States. AGEBs are fairly small urban areas with more than 2,500 inhabitants and relatively homogeneous socioeconomic characteristics. In the work reviewed above, one-kilometer zones and AGEB-level data were also the rule. We have examined data using two and five kilometers as well; the former is very much like what we report here, while the five-kilometer data show much weaker correlations with emissions, as would be expected if the one-kilometer tradition is well-founded.

About a third of the plants were not within a kilometer of any AGEB, or (in a few cases) were near one which had no IMU available data. Presumably, these were cases of AGEBs with very low populations. It is for this reason that we phrase our results as characterizing *urban* emissions sources, saying nothing of the pattern among all sources. Note also that much of the work reviewed above also eliminated low-population AGEBs prior to analysis.

The IMU was calculated by the Mexican government's National Population Council (*Consejo Nacional de Población*, or CONAPO) on the basis of census data in 2000 and 2010 and a subset of questions asked in count 2005. The surveys measure aspects of education, housing, health, and diagnostic of poverty but not income per se, which is largely unavailable in Mexican census data and considered very unreliable among the poor, even when measured. IMU is the first principal component of the underlying socioeconomic variables. The indices generated are categorized into five classes of "very high," "high," "medium," "low," and "very low," with positive numbers classified as highly marginalized and negative numbers as low marginalized. However, some of the variables change from 2000 to 2005 and 2010. For example, among the three surveys on which we rely, the earliest (2000) measured those without post-primary education, while the latter two measured those without secondary education, and a question about proper roofing material was replaced by one regarding mud floors (see Tables II, III, and IV). Even across the two periods where the same variables are used, the IMU is not comparable since it is scaled against concurrent data only. This is the main reason we are not exploiting the apparent panel structure of the data.

**Table I: Average Water Emissions 2004-2012 and Average Marginalization Index, 2000, 2005, and 2010**

| Variable | Obs. | Mean | Standard deviation | Min | Max |
|---|---|---|---|---|---|
| ***Average emissions in 2004-2006*** | | | | | |
| Arsenic | 1,742 | .0236649 | .3227589 | 5.63e-16 | 8.21 |
| Cadmium | 1,531 | .0259535 | .3449936 | 2.00e-13 | 10.437 |
| Chromium | 1,521 | .0776544 | 1.103168 | 4.80e-13 | 36.239 |
| Cyanide | 1,748 | .020477 | .2247921 | 5.63e-16 | 6.122 |
| Lead | 1,647 | .0900227 | .9967671 | 2.80e-12 | 23.696 |
| Mercury | 1,703 | .012735 | .2386985 | 1.00e-13 | 8.21 |
| Nickel | 1,626 | .1089167 | 1.73273 | 2.50e-12 | 53.623 |
| ***Average emissions in 2007-2009*** | | | | | |
| Arsenic | 1,484 | .0283263 | .3663805 | 8.17e-20 | 9.944522 |
| Cadmium | 1,430 | .2050393 | 4.128099 | 7.57e-20 | 147.1176 |
| Chromium | 1,413 | .5071285 | 9.630976 | 2.00e-18 | 317.2854 |
| Cyanide | 1,520 | .1893542 | 4.716215 | 7.57e-20 | 180.578 |
| Lead | 1,539 | 14.84403 | 571.5088 | 3.00e-18 | 22420.13 |
| Mercury | 1,447 | .6370056 | 22.70032 | 1.51e-20 | 862.3125 |
| Nickel | 1,525 | 22.98928 | 868.6105 | 9.00e-18 | 33917.63 |
| ***Average emissions in 2010-2012*** | | | | | |
| Arsenic | 670 | .0194004 | .1808584 | 3.00e-13 | 3.084723 |
| Cadmium | 660 | .0317657 | .1906046 | 1.00e-13 | 2.665539 |
| Chromium | 686 | .2874099 | 2.376698 | 2.10e-12 | 31.31504 |
| Cyanide | 659 | .0545624 | .8471858 | 2.65e-12 | 21.28291 |
| Lead | 714 | .1350655 | 1.141904 | 2.00e-12 | 20.47721 |
| Mercury | 635 | .0036327 | .0277404 | 1.00e-13 | .4224601 |
| Nickel | 767 | .3308526 | 3.474742 | 4.00e-12 | 64.27579 |
| ***Average marginalization index (IMU)*** | | | | | |
| 2000 | 3,558 | -1.653979 | 1.605746 | -4.381406 | 6.78143 |
| 2005 | 3,611 | -.5891976 | .5370447 | -1.424342 | 2.70139 |
| 2010 | 3,625 | -.5421705 | .5641612 | -1.612321 | 3.333449 |

*Note*. All pollution data are in kilograms.

**Table II: Correlation Coefficient of Marginalization Index and Socioeconomic Variables, 2000**

| Category or type of indicator | Indicators (percent, unless otherwise indicated) | Correlation with IMU |
|---|---|---|
| Education | Population between ages 6 and 14 who do not attend school | 0.7071 |
| | Population 15 years and above without post-primary education | 0.8981 |
| Income/status | Employees earning no more than twice the minimum wage | 0.8041 |
| | Houses without drainage | 0.6499 |
| | Houses without piped water | 0.8761 |
| | Houses without proper roofing material | 0.6234 |
| | Houses without refrigerator | 0.8505 |
| | Houses with overcrowding | 0.9230 |
| Demographic | Child mortality rate of women between ages 15 and 49 | 0.7457 |
| | Population without access to health services | 0.6659 |
| | Women between 12 and 17 years of age with at least one live childbirth | 0.4318 |

**Table III: Correlation Coefficient of Marginalization Index and Socioeconomic Variables, 2005**

| Category or type of indicator | Indicators (percent, unless otherwise indicated) | Correlation with IMU |
|---|---|---|
| Education | Population between 6 and 14 that do not attend school | 0.6327 |
| | Population 15 years and above without secondary education | 0.8341 |
| Income/status | Houses without drainage | 0.6572 |
| | Houses without piped water | 0.8240 |
| | Houses with mud floor | 0.7243 |
| | Houses without refrigerator | 0.8274 |
| | Houses with overcrowding | 0.8934 |
| | Houses without septic connection | 0.9163 |
| Demographic | Child mortality rate of women between ages 15 and 49 | 0.6430 |
| | Population without access to health services | 0.7216 |

**Table IV: Correlation Coefficient of Marginalization Index and Socioeconomic Variables, 2010**

| Category or type of indicator | Indicators (percent, unless otherwise indicated) | Correlation with IMU |
|---|---|---|
| Education | Population between ages 6 and 14 who do not attend school | 0.6064 |
| | Population 15 years and above without secondary education | 0.8281 |
| Income/status | Houses without drainage | 0.6199 |
| | Houses without piped water | 0.8330 |
| | Houses with mud floor | 0.6613 |
| | Houses without refrigerator | 0.8453 |
| | Houses with overcrowding | 0.8660 |
| | Houses without septic connection | 0.9123 |
| Demographic | Child mortality rate of women between ages 15 and 49 | 0.6480 |
| | Population without access to health services | 0.5895 |

## 4. Methods and Results

We present the results from bivariate cross-section regressions:

$$lPoll_{ist} = \alpha + \beta IMU_{it} + \varepsilon_{ist} \quad (1)$$

Where $t$ refers to the two time periods from 2004 to 2006 and 2009 to 2011; $lPoll_{ist}$ is the log of average toxic emissions of substance $s$ by plant $i$ and in time period $t$; and $IMU_{it}$ is the Urban Marginalization Index (the principal component constructed from ten to eleven underlying socioeconomic variables selected by CONAPO). Since our preliminary analysis focuses on correlation and not causation, we assign the marginalization index data from 2005 and 2010 to the corresponding centered emissions averages for a period of three years; i.e., emissions data from 2004-2006 was regressed on marginalization data from the 2005 count data, and those from 2009-2011 on the 2010 census data.[6]

The overviews of what we observed are presented in Tables V and VI, which contain coefficients from separate regressions of the logarithm of emissions into water for each of seven toxic metals in each of the time periods listed above. The association between emissions and marginalization is positive (though not always statistically significant) and gets larger over time (although there are variations across pollutants), even as the total number of plants reporting positive emissions falls. Meanwhile, according to SEMARNAT (2013), the total number of enterprises filing reports for all pollutants and all disposal media roughly doubled. It appears, then, that firms were finding alternatives to releasing these substances into water, while among those that continued to do so, the association between quantity released and social class grew stronger.

[6] In order to incorporate all the emissions data, we present results in the appendix with 2004-2006, 2007-2009 and 2010-2012 averages with corresponding IMU data from the census 2000, count 2005, and census 2010 respectively. Overall, the results are similar.

Even in the earliest cross section, that association is large (see Table V). For chromium, an increase in IMU is associated with an emissions increase of about 66%. For lead and nickel, the rise is 47%; for cyanide, emissions increase by 35%; and for mercury, arsenic, and cadmium, the effects are closer to 14% or less. By 2010, all the associated effects increased in magnitude (see Table VI), although with the reduced sample size, only the effects in excess of half a log point (i.e., a 65% increase) are statistically significant. For chromium, emissions increase by about 72%; for lead, magnitude falls to about 43%; for nickel, the magnitude rises to about 57%; for cyanide, the associated emissions increase is almost 87%; for arsenic, the increase in emissions is 72%; for mercury, the coefficient increases to 49%; and for cadmium, to about 35%.

The inaccuracies in the pollution reports discussed in the last section mean these estimates are all likely to be smaller than the true association. This is because they appear not to result from any attempt to deceive regulators or the public. Rather, they result from carelessness and the lack of standardized monitoring protocols. The measurement error to which they give rise should therefore be random (and in the event, the symptoms of error show very weak correlation with the marginalization index). Since random measurement error biases regression coefficients towards zero (i.e., attenuation bias), the results below are most likely to understate the actual association. The strong reservations about quantitative estimates, therefore, do not apply to the results in the qualitative form we have emphasized: Plants in poor communities emit more of these metals into water.

In Tables VII and VIII, we present quantile regressions, a way of examining nonlinearity of the underlying associations approximated by the above regression coefficients. The coefficients reported can be interpreted very much like those from OLS by focusing on distinct parts of the distribution of emissions. Just as an OLS coefficient measures the predicted change in *mean* log-emissions associated with a unit change in IMU, each of these measures the predicted change in some *quantile* of the log-emissions distribution. For example, the 0.5 at the bottom of the first column in Table VII implies that an otherwise random sample with IMU one unit above average is expected to have an arsenic distribution with its top decile half a log point above average.

The outstanding pattern in these results is that coefficient estimates are higher at the higher deciles. A unit increase in marginalization is associated with a large increase in emissions from plants that would have polluted a lot anyway, and a small increase (or sometimes a decrease, and never statistically significant) from those would have polluted little. Since the overall effect is positive, this suggests that a curve with positive second derivative would fit these data better than the linear model, and that those living in the most marginalized communities suffer pollution burdens even greater than our linear estimates suggest.

**Table V: Linear Regressions of Log Emissions 2004-2006 on Marginalization Index (IMU) from 2005**

| | (1) Arsenic | (2) Cadmium | (3) Chromium | (4) Cyanide | (5) Lead | (6) Mercury | (7) Nickel |
|---|---|---|---|---|---|---|---|
| IMU | 0.126 | 0.124 | 0.660** | 0.355 | 0.471* | 0.142 | 0.467* |
| | (0.255) | (0.256) | (0.261) | (0.255) | (0.252) | (0.256) | (0.241) |
| constant | -11.808*** | -10.321*** | -9.379*** | -10.377*** | -8.544*** | -12.855*** | -8.262*** |
| | (0.204) | (0.206) | (0.213) | (0.205) | (0.202) | (0.202) | (0.191) |
| $R^2$ | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| $N$ | 1,082 | 956 | 967 | 1,097 | 1,033 | 1,067 | 1,032 |

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

**Table VI: Linear Regressions of Log Emissions 2009-2011 on Marginalization Index (IMU) from 2010**

| | (1) Arsenic | (2) Cadmium | (3) Chromium | (4) Cyanide | (5) Lead | (6) Mercury | (7) Nickel |
|---|---|---|---|---|---|---|---|
| IMU | 0.723** | 0.345 | 0.716** | 0.872*** | 0.431 | 0.490 | 0.569* |
| | (0.337) | (0.344) | (0.345) | (0.331) | (0.321) | (0.354) | (0.300) |
| constant | -11.183*** | -9.938*** | -8.765*** | -9.894*** | -8.326*** | -12.438*** | -8.161*** |
| | (0.267) | (0.273) | (0.265) | (0.261) | (0.251) | (0.273) | (0.243) |
| $R^2$ | 0.01 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 |
| $N$ | 493 | 451 | 458 | 474 | 484 | 449 | 497 |

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

**Table VII: Quantile Regressions of Log Emissions 2004-2006 on Marginalization Index (IMU) from 2005**

| Quantiles | (1) Arsenic | (2) Cadmium | (3) Chromium | (4) Cyanide | (5) Lead | (6) Mercury | (7) Nickel |
|---|---|---|---|---|---|---|---|
| 10% | 0.152 | 0.202 | 0.626 | 0.209 | 0.429 | -0.716 | 0.879 |
| | (1.037) | (0.417) | (1.066) | (0.672) | (0.851) | (0.820) | (0.647) |
| 25% | 0.163 | 0.298 | 0.778** | -0.025 | 0.472 | -0.036 | 0.534** |
| | (0.460) | (0.408) | (0.366) | (0.398) | (0.333) | (0.412) | (0.253) |
| 50% | 0.303 | 0.248 | 0.804** | 0.231 | 0.419 | 0.257 | 0.406 |
| | (0.331) | (0.233) | (0.317) | (0.396) | (0.257) | (0.205) | (0.273) |
| 75% | 0.303 | 0.175 | 0.884*** | 0.690*** | 0.482*** | 0.277 | 0.775*** |
| | (0.239) | (0.362) | (0.310) | (0.236) | (0.172) | (0.288) | (0.186) |
| 90% | 0.508*** | 0.208 | 0.931* | 0.905** | 0.966*** | 0.330 | 0.497** |
| | (0.188) | (0.403) | (0.488) | (0.424) | (0.280) | (0.396) | (0.208) |
| *N* | 1,082 | 956 | 967 | 1,098 | 1,033 | 1,067 | 1,032 |

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

**Table VIII: Quantile Regressions of Log Emissions 2009-2011 on Marginalization Index (IMU) from 2010**

| Quantiles | (1) Arsenic | (2) Cadmium | (3) Chromium | (4) Cyanide | (5) Lead | (6) Mercury | (7) Nickel |
|---|---|---|---|---|---|---|---|
| 10% | 0.047 | -0.504 | 0.803 | -0.439 | -0.689 | -0.563 | 0.223 |
| | (0.899) | (1.112) | (0.938) | (0.812) | (0.848) | (0.884) | (0.983) |
| 25% | 0.277 | -0.342 | 0.033 | 0.789 | 0.034 | 0.129 | 0.186 |
| | (0.507) | (0.705) | (0.387) | (0.722) | (0.725) | (0.630) | (0.389) |
| 50% | 0.876** | 0.460 | 0.753* | 0.909*** | 0.243 | 0.360 | 0.830** |
| | (0.406) | (0.313) | (0.443) | (0.321) | (0.382) | (0.415) | (0.337) |
| 75% | 1.068*** | 0.766* | 1.120* | 1.375*** | 0.843*** | 0.842** | 0.965*** |
| | (0.349) | (0.426) | (0.660) | (0.479) | (0.294) | (0.408) | (0.304) |
| 90% | 1.391*** | 0.488 | 1.093 | 1.057 | 1.153*** | 1.358** | 0.660* |
| | (0.520) | (0.314) | (0.847) | (0.801) | (0.258) | (0.546) | (0.362) |
| *N* | 493 | 451 | 458 | 474 | 496 | 449 | 497 |

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

## 5. Conclusions

There is a strong negative association between toxic emissions into water and socioeconomic status of the surrounding population in all three cross sections of Mexican plants we examined. This can be due to a combination of plants choosing emissions abatement with an eye towards the likelihood of community protest, wealthy people moving away from plants with higher emissions, and other factors that influence both industry practice and choice of residence. As mentioned, our ongoing work is aimed at isolating the first of these causal channels.

The results presented are bivariate correlations between toxics emissions and marginalization status of the surrounding populations. We do not capture the idiosyncratic effects of industries, geographical differences including stringency of regulators as well as political factors. The work in progress consists of measurement of such confounders and of potential instrumental variables, as well as refinement of the data used, so that we can measure magnitudes of effects rather than settling for the weaker statement above that these are likely underestimates. Meanwhile, those whose knowledge of Mexico includes the observation that more prosperous communities live closer to sources of industrial pollution, than poorer communities, should be made aware that industries near more marginalized communities emit more pollution.

# 6. Appendix

**Table A1: Linear Regressions of Log Emissions 2004-2006 on Marginalization Index (IMU) from 2000**

| Coefficients | (1) Arsenic | (2) Cadmium | (3) Chromium | (4) Cyanide | (5) Lead | (6) Mercury | (7) Nickel |
|---|---|---|---|---|---|---|---|
| IMU | 0.029 | 0.090 | 0.260*** | 0.190** | 0.236*** | 0.084 | 0.195** |
| | (0.090) | (0.092) | (0.095) | (0.088) | (0.087) | (0.087) | (0.087) |
| constant | -11.819*** | -10.227*** | -9.331*** | -10.259*** | -8.404*** | -12.780*** | -8.202*** |
| | (0.202) | (0.207) | (0.214) | (0.196) | (0.196) | (0.193) | (0.194) |
| $R^2$ | 0.00 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 |
| *N* | 1,070 | 943 | 950 | 1,084 | 1,017 | 1,055 | 1,018 |

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

**Table A2: Linear Regressions of Log Emissions 2007-2009 on Marginalization Index (IMU) from 2005**

| Coefficients | (1) Arsenic | (2) Cadmium | (3) Chromium | (4) Cyanide | (5) Lead | (6) Mercury | (7) Nickel |
|---|---|---|---|---|---|---|---|
| IMU | 0.293 | 0.122 | 0.703*** | 0.575** | 0.329 | 0.376 | 0.474* |
| | (0.274) | (0.269) | (0.263) | (0.262) | (0.250) | (0.271) | (0.253) |
| constant | -11.383*** | -9.968*** | -8.922*** | -9.824*** | -8.213*** | -12.276*** | -7.908*** |
| | (0.207) | (0.202) | (0.194) | (0.196) | (0.187) | (0.203) | (0.190) |
| $R^2$ | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 |
| *N* | 860 | 834 | 835 | 877 | 901 | 841 | 892 |

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

**Table A3: Linear Regressions of Log Emissions 2010-2012 on Marginalization Index (IMU) from 2010**

| Coefficients | (1)<br>Arsenic | (2)<br>Cadmium | (3)<br>Chromium | (4)<br>Cyanide | (5)<br>Lead | (6)<br>Mercury | (7)<br>Nickel |
|---|---|---|---|---|---|---|---|
| IMU | 0.605 | 0.435 | 0.825** | 0.922** | 0.377 | 0.452 | 0.504 |
| | (0.418) | (0.403) | (0.396) | (0.415) | (0.374) | (0.432) | (0.350) |
| _cons | -10.169*** | -8.692*** | -7.356*** | -8.847*** | -7.304*** | -11.445*** | -7.025*** |
| | (0.294) | (0.288) | (0.283) | (0.288) | (0.267) | (0.304) | (0.260) |
| $R^2$ | 0.01 | 0.00 | 0.01 | 0.02 | 0.00 | 0.00 | 0.01 |
| *N* | 317 | 315 | 326 | 305 | 345 | 295 | 368 |

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

**Table A4: Quantile Regressions of Log Emissions 2004-2006 on Marginalization Index (IMU) from 2000**

| Quantiles | (1)<br>Arsenic | (2)<br>Cadmium | (3)<br>Chromium | (4)<br>Cyanide | (5)<br>Lead | (6)<br>Mercury | (7)<br>Nickel |
|---|---|---|---|---|---|---|---|
| 10% | 0.054 | 0.090 | 0.227 | 0.279 | 0.407 | 0.140 | 0.371 |
| | (0.378) | (0.283) | (0.318) | (0.207) | (0.277) | (0.304) | (0.258) |
| 25% | 0.112 | 0.093 | 0.333*** | 0.159 | 0.250** | 0.046 | 0.225*** |
| | (0.158) | (0.150) | (0.111) | (0.105) | (0.118) | (0.139) | (0.081) |
| 50% | 0.080 | 0.107 | 0.236** | 0.126 | 0.178* | 0.064 | 0.158** |
| | (0.113) | (0.107) | (0.120) | (0.103) | (0.104) | (0.071) | (0.079) |
| 75% | 0.034 | 0.080 | 0.263*** | 0.232** | 0.181* | 0.079 | 0.268** |
| | (0.117) | (0.124) | (0.091) | (0.099) | (0.092) | (0.067) | (0.116) |
| 90% | 0.067 | 0.185 | 0.416*** | 0.308* | 0.412*** | 0.181 | 0.208* |
| | (0.139) | (0.158) | (0.129) | (0.180) | (0.136) | (0.145) | (0.124) |
| *N* | 1,070 | 943 | 950 | 1,084 | 1,017 | 1,055 | 1,018 |

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

**Table A5: Quantile Regressions of Log Emissions 2007-2009 on Marginalization Index (IMU) from 2005**

| Quantiles | (1) Arsenic | (2) Cadmium | (3) Chromium | (4) Cyanide | (5) Lead | (6) Mercury | (7) Nickel |
|---|---|---|---|---|---|---|---|
| 10% | -0.136 | -0.036 | -0.009 | -0.182 | 0.129 | -0.070 | 0.776 |
| | (0.829) | (0.988) | (0.915) | (0.632) | (1.082) | (1.033) | (0.771) |
| 25% | -0.065 | -0.317 | 0.448** | 0.672 | 0.057 | 0.257 | 0.292 |
| | (0.302) | (0.483) | (0.206) | (0.548) | (0.436) | (0.350) | (0.376) |
| 50% | 0.223 | -0.066 | 1.028*** | 0.624** | 0.347 | 0.555* | 0.378 |
| | (0.251) | (0.267) | (0.220) | (0.260) | (0.299) | (0.308) | (0.354) |
| 75% | 0.709** | 0.408 | 0.618*** | 0.935*** | 0.432 | 0.403 | 0.614** |
| | (0.298) | (0.281) | (0.193) | (0.324) | (0.269) | (0.257) | (0.245) |
| 90% | 1.049** | 0.691*** | 1.512*** | 1.673*** | 1.071*** | 0.587 | 0.565** |
| | (0.420) | (0.258) | (0.281) | (0.422) | (0.301) | (0.525) | (0.271) |
| *N* | 860 | 834 | 835 | 877 | 901 | 841 | 892 |

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

**Table A6: Quantile Regressions of Log Emissions 2010-2012 on Marginalization Index (IMU) from 2010**

| Quantiles | (1) Arsenic | (2) Cadmium | (3) Chromium | (4) Cyanide | (5) Lead | (6) Mercury | (7) Nickel |
|---|---|---|---|---|---|---|---|
| 10% | 0.775 | -1.075 | -0.156 | 1.565 | 0.000 | -0.664 | -1.257 |
| | (1.113) | (1.508) | (1.120) | (1.481) | (1.365) | (1.059) | (1.439) |
| 25% | 0.751 | 0.667 | 0.833** | 1.296*** | 0.149 | 1.108* | 0.161 |
| | (0.872) | (0.790) | (0.361) | (0.452) | (0.598) | (0.661) | (0.676) |
| 50% | 0.913** | 0.550 | 0.682* | 1.159*** | 0.506* | 0.451 | 0.683*** |
| | (0.402) | (0.408) | (0.369) | (0.414) | (0.299) | (0.284) | (0.136) |
| 75% | 0.674* | 0.837** | 0.948* | 1.006** | 0.666 | 0.789** | 0.330 |
| | (0.382) | (0.423) | (0.568) | (0.486) | (0.430) | (0.390) | (0.377) |
| 90% | -0.071 | 0.509 | 0.942 | 0.347 | 0.545* | 0.307 | 0.790*** |
| | (0.492) | (0.594) | (0.688) | (0.724) | (0.284) | (0.729) | (0.300) |
| *N* | 317 | 315 | 326 | 305 | 345 | 295 | 368 |

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

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