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Abstract

This paper identifies a number of errors and inconsistencies in a series of air pollution intensities for Mexico that were recently created by the World Bank. Because these data are being used to conduct public policy analysis and advice for Mexico and countries at similar levels of development, knowledge of the limits of these data is of utmost importance. In addition to identifying the problems with these data, this paper makes a series of adjustments to offer a corrected dataset. These newly corrected data are available on the World Bank's New Ideas in Pollution Regulation (NIPR) web page.

Introduction

Since the late 1980s, the World Bank (WB) has provided an invaluable set of tools for researchers concerned with environmental degradation in developing countries. In the absence of reliable data on industrial pollution in the developing world, the WB has created a series of datasets that have given the research community the opportunity to better understand levels of pollution in developing countries, and therefore issue policy advice with more clarity.

From the outset, these datasets have proved to be very informative. Recently however, the WB recognized that there were limitations to the use of the earliest pollution coefficients because they were solely based on estimates of contamination in the United States. In a marked improvement, the WB embarked on the creation of a second phase of pollution coefficients with actual data from the developing countries. The WB has now made data available for Mexico and China, and these data have been used as proxies for countries at similar stages of development. It is true that work in the second phase is still in its infancy, but research for this paper has identified a number of errors and shortcomings in the construction of the Mexico data. In addition to pointing out some of these shortcomings, we offer a corrected set of intensities that can be used until these data are replaced by better estimates.

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In 1997, the WB, with information from Mexico's National Institute of Ecology (INE), published a series of air pollution intensity estimates for Mexican industry. The intensities are expressed as tons of pollution per employee, and are provided for small, medium, and large sized firms for 28 industrial branches in Mexico. In addition to these data categorized by firm size, the WB created "overall" coefficients intended to be general representations of air pollution intensity for each industrial branch as a whole. The latter coefficients are the focus of concern throughout most of this paper.

We are able to prove that the "overall" coefficients are inadequate representations of the levels of air pollution for each industrial branch in Mexico. We show that the data reported by the WB are generally less pollution intensive than a properly calculated series of "overall" coefficients would be. This paper will show that the measurement errors in the WB coefficients are the result of three shortcomings:

- The WB data does not represent the regional distribution of Mexican industry well enough to serve as a proxy for Mexican industry as a whole. The sample of air pollution data that was used to create the intensities includes data from only one industrial region in Mexico, the Metropolitan Area of the Valley of Mexico (MAVM). Only 30% of value added production in Mexican manufacturing comes out of this region, and some industries don't even exist in the MAVM.
- The WB data does not represent the size distribution of Mexican industry well enough to serve as a proxy for Mexican industry as a whole. A "size bias" was introduced into the "overall" coefficients because the WB may have created them by taking the weighted average of the WB sample, not the weighted average of the size distribution of firms in the Mexican economy. Since the WB sample included an abundance of large firms, the coefficients are biased away from smaller firms--which are "dirtier" on average than large ones.
- Expressing pollution intensity as pollution per employee is not an adequate measure of performance. Pollution per employee can vary independently of output levels, and as will be shown, can lead to qualitatively different results from coefficients expressed in their proper form—pollution per unit of output.

In addition to these problems, there are a number of minor technical errors and inconsistencies in the WB data for Mexico. In this paper, after discussing the three major shortcomings noted above we will describe those errors, and will correct for them wherever possible.

This paper is divided into four parts. First, we will briefly describe the development of the WB's first phase of industrial pollution data construction, the Industrial Pollution Projection System (IPPS). Second, we will discuss the origins and development of the second phase, the air pollution intensities for Mexico. In the third part we will examine shortcomings with these data in detail, and calculate a corrected set of air pollution intensities. Fourth, we will briefly describe other problems with the data that were not in our power to correct. Drawing on this work, we will conclude by urging the WB to create a more accurate set of pollution intensities for Mexico.

I. Phase 1: The Industrial Pollution Projection System

In an effort to alleviate a problem that has frustrated researchers for quite some time -- the extremely limited availability of pollution data in the developing world-- the WB has developed a number of tools to assist decision-makers in the estimation of the environmental effects of industrial activity in developing countries. The majority of this work can be found on the World Bank's New Ideas in Pollution Regulation web page (World Bank, 2001). This section briefly describes the first phase of the WB work in this area, the Industrial Pollution Projection System (IPPS).

The early flagship of the WB's efforts, begun in the 1980s was the creation of the Industrial Pollution Projection System (IPPS). The IPPS was established "to exploit the fact that industrial pollution is heavily affected by the scale of industrial activity and its sectoral composition" (Hettige et al, 1994, 2). Based on 1987 estimates of industrial pollution in the United States, where data is more prevalent, the IPPS provides pollution intensities for a variety of pollutants, including those for air, soil, water and others. These intensities are presented as pollution per unit of output or per employee for various branches of industry. Because these data are available for only one year, using IPPS forces researchers to assume constant emissions per unit of activity when estimating changes in industrial pollution over time.

IPPS has been used, among other places, for Brazil, Latvia, India, Vietnam, Central and Latin America. The first use of these coefficients to estimate industrial pollution in Mexico occurred in 1993. Based on this approach, it was estimated that the composition of Mexican industry became 50 percent more pollution intensive between 1950 and 1970, and 25 percent more pollution intensive between 1970 and 1989. Regarding the overall scale of industrial pollution, the study found that Mexican manufactures were producing 20 times more pollution in 1989 than in 1950 (Ten Kate, 1993).

More recent studies continue to utilize the IPPS coefficients for analyses of Mexico. Other studies looked at the scale and composition of Mexican manufacturing in a manner similar to Ten Kate (Mercado, Dominguez and Fernandez, 1993; Aroche, 1999). The IPPS coefficients have also been used to examine the maquiladora industry (Barkin 1999; Mercado, 1998). From a public policy perspective, a recent study used the IPPS when looking at the environmental benefits of ecological taxes in Mexico (Fernandez, 1998). Most recently, the IPPS coefficients were used to estimate whether the Mexican exporting industry has become more or less pollution intensive after the signing of NAFTA (Schatan, 2000). Another study also examines the composition and scale effects of industry using IPPS for all of Latin America (Schatan, 1999).

Estimates using IPPS can, at best, serve to suggest general directions and trends. However, they are flawed by their dependence on the implausible assumption that every industry in a developing country has the same pollution intensity as the corresponding U.S. industry had in 1987. With the creation of Mexico intensities, the World Bank has taken a positive first step in moving beyond the IPPS methodology.

II. Phase 2: The World Bank Air Pollution Intensities for Mexico

This section describes the WB air pollution intensities for Mexico. In addition to the fact that the IPPS coefficients are now fairly outdated, one of the most recognized limitations of the IPPS data is the assumption that those industries that are clean or dirty in the United States are also clean or dirty in the developing world. In the late 1990s, the WB recognized the need to create developing country specific pollution measures, and established a series of air pollution intensities for Mexico and China. Following a discussion of the origins of the Mexico air pollution data that were used by the WB, this section will describe the construction of the WB intensities for Mexico. This exercise reveals two puzzling findings. First, Mexico's National Institute of Ecology (INE) staff has no clear recall of the process undertaken with the WB to create these data, although the WB refers to this work as a "collaboration" with INE. Second, the WB, when asked about the creation of the data, has not been able to recollect or recreate its methodology.

Mexico's overarching legislation for environmental policy is called the General Law of Ecological Equilibrium and Environmental Protection (LGEEPA). LGEEPA provides the federal regulatory framework for most of the obligations, authority, and administration related to the environment in Mexico. LGEEPA outlines a series of requirements for air pollution control in Mexico, including a particular set of regulations pertaining to the industrial sector. Many of the key industrial sectors, but not all, fall under federal jurisdiction: oil and petrochemicals sectors, industrial chemicals, ink, metallurgy, automotive, pulp and paper, cement and lime, asbestos, the glass industry, and finally energy and hazardous waste producers. A component of the requirements for these industries is the reporting of air emissions. All other sectors are monitored by local authorities.

Those industries that fall under federal jurisdiction must report emissions in two forms. New firms in Mexico are required to obtain a Licencia Ambiental Única (LAU) --a license granted to a firm after it has successfully completed an environmental impact statement. Initial sets of emissions data are obtained by INE as part of the LAU process. After a plant under federal jurisdiction is up and running, such firms are required to file annual reports called Cédula de Operación Annual (COA). Data from both LAU and COA should be fed into the National System of Information for Fixed Sources (Sistema Nacional de Información de Fuentes Fijas, or SNIFF), and the Pollution Transfer and Emissions Registration (RETC). In reality however, these databases consist solely of data from the COA, apparently due to a lack of communication between the divisions of INE responsible for LAU and for COA.

The WB reports that it used data from SNIFF to create the air pollution intensities for Mexico. SNIFF has evolved into a significantly large database that now contains a myriad of information on the nation's fixed sources of pollution. In addition to emissions data for five criteria air pollutants, Nitrous Oxides (NOx), Sulphur Oxides (SOx), Particulate Matter (PT), Carbon Monoxide (CO), and Hydrocarbons (HC), SNIFF also has information on: the type and quantity of energy consumed from each industrial source, the type and placement of energy combustion equipment at each industrial plant, the number of chimneys and smokestacks at a facility, in addition to basic economic data such as the number of workers at

a plant. As part of COA, beginning in 1997, annual reporting of such information has become mandatory for those sectors under federal jurisdiction, and is now published in an annual report published by INE.

INE collects emissions data in two ways. For some firms, particularly those that are required to report to COA, emissions are reported from monitoring systems located directly at industrial facilities. For other firms, emissions are estimated using the AP-42 methodology created by the United States Environmental Protection Agency. Such an approach creates engineering based "emissions factors" that are estimated using information on a firm's energy use, technology, production process, pollution control equipment, and production inputs that are also reported to COA (INE, 1996; INE/SEMARNAP, 1999). It is important to note however, that most of the calculations resemble AP-42 methods: "in general, measuring of pollution emissions is the result of the algebraic product of an emission factor and its responsive industry activity data" (Inventario de Emisiones, 1996). In addition, because certain industries do not fall under federal jurisdiction, the SNIFF is not representative of the whole of Mexican industry. For example, the food and beverages industries, in addition to the textiles industry, are underrepresented in SNIFF. In 1996, data were available for only 482 of the 3,831 textiles plants in the MAVM (INEGI, 1994).

With data from SNIFF the WB calculated pollution intensities for 28 industrial branches and five pollutants classified by firm size, and created what they call "overall" coefficients (coefficients that represent Mexican industries as a whole). Specifically, the World Bank database provides estimates for the amount of pollution intensity produced per employee by specific industry sectors in Mexico. Like the original IPPS estimates, the Mexican estimates are available for a single year and therefore it is impossible to estimate the impact of technical change over time.

The pollution intensities are at 2 and 3-digit International Standard Industrial Classification (ISIC) (version 2) code levels. The intensities were calculated for three firm size categories: small, medium, large. The Bank defines small firms as those having twenty or fewer employees, medium firms as having employment between 21 and 100, and large firms as those with employment over 100. The sample size for intensities was distributed across each firm size: small firms 2,346; medium firms 2,143, large firms 1,310. In addition, the Bank reports that "preliminary analysis of results revealed an outlier problem. Therefore, the top twenty-five polluters were deleted from the overall dataset, and the top ten polluters from each plant-size category were removed, before calculation of pollution intensities." (NIPR, 2000).

Based on interviews with high-level administrators at INE and correspondence with key members of the WB research team, it was striking to learn how little knowledge now exists about the origin and development of the WB intensities. At INE, the surveyed respondents indicated that they were not at all aware of the WB intensities (Coordinator of Programs, DGGIA; Emissions Inventory Deputy Direction, DGGIA). It is known that the emissions inventories can be obtained through official requests to INE. Based on our interviews then, rather than a WB-INE "collaboration" we conclude that the WB simply made such a request. Correspondence with the WB was just as puzzling. The WB reports that it

cannot gain access to their database in such a way as to decipher the exact methodology used to create the intensities (WB, 2000).

Using the new estimates to evaluate the air pollution intensity of Mexican manufactures, Rhys Jenkins found contrary results to Ten Kate. Where Ten Kate found a 25 percent increase in pollution intensity in Mexican manufactures from 1970 to 1989, Jenkins' research found no general increase in pollution intensity over the period. Jenkins was also able to examine pollution intensity from 1988 to 1995. Here, Jenkins observed a reduction in the air pollution contaminants. The rest of his paper resorts back to the U.S. based, IPPS coefficients. He finds that for almost all of the air pollutants, the pollution intensity of Mexico's export oriented manufactures in 1990 is greater than the pollution intensity of protected industries in 1979 (Jenkins, 1998). A comparison of the Mexican intensities with the IPPS data revealed that some industries in Mexico are significantly cleaner than their US counterparts (Gallagher, 2001).

III. Toward a Phase 3: Identifying and Correcting for Problems in the World Bank Intensities for Mexico

This section will describe, and to the extent possible correct for, three fundamental problems with the WB air pollution intensities for Mexico: the WB coefficients do not adequately represent the regional distribution of Mexican industry; the WB coefficients do not adequately represent the size distribution of Mexican industry; and expressing the coefficients as pollution per employee is not a useful measure of economic activity. A number of smaller but important errors and inconsistencies with the data are reported in the next section.

Regional Bias

The WB air intensities are intended to be representative of industrial pollution for the entire Mexican economy, but the sample of industries used for the calculations consists only of industry in the MAVM. This introduces a regional bias in the WB coefficients because levels of industrial composition, technology, and environmental policy in the MAVM are not always mirrored in the rest of the Mexican economy.

According to our interviews with officials at INE, the only data available to the WB at the time of the construction of the WB intensities were from the MAVM. This is a problem because total value added production for manufacturing in the MAVM is only 30 percent of total value added for Mexican manufacturing as a whole. In some industries, the industrial share of MAVM manufacturing is much smaller than 30 percent, especially in those industries that are the most resource intensive and those that have been most affected by structural change.

Table III.1 shows value added production for each industrial branch in the MAVM as a percentage of total value added production in each branch for the entire Mexican economy as reported by the Mexican industrial census. The table is split into four categories, ranging from those industries in the MAVM that comprise less than 25 percent of total value added in Mexico, to those that account for more than 50 percent.

MAVM production is less than 25 percent of total production in 12 of the 28 industrial branches in the WB sample, representing 50 percent of total Mexican manufacturing. It is striking how little of some of the most heavily polluting industries resides in MAVM: zero percent of total Oil refining, 5.9 percent of Iron and Steel, 13.9 percent of Petrochemicals, 18.1 percent of the Cement industry, 23.9 percent of Food Products, and 24 percent of the Beverage industry are located in the MAVM. The case of Oil refining is particularly puzzling because no such industries exist in the MAVM. Our research revealed that SNIFF inventories do include separate information for the oil industry that are directly supplied by Pemex (the national oil industry). Perhaps these data were added to the WB sample, but such information is not provided.

There are 9 industries whose production in the MAVM is more than 40 percent of total Mexican production. These industries include "other chemicals" which comprises of the cosmetics, pharmaceuticals and similar industries; rubber, textiles, glass and apparel. Therefore the coefficients for these industries can be used with more confidence than those described above, but with some caveats. On the one hand, Mexican industry is more regulated for air pollution than in other parts of Mexico, but on the other hand the vintage of plants in the MAVM area is considered to be older[3].

The regional bias reveals that the WB intensities as published should be used with extreme caution. While it is certainly true that using firms in MAVM as a proxy for Mexican industry as a whole is markedly better than using pollution levels in the U.S. for 1987, researchers should report the shortcomings of the WB data before drawing conclusions about industries with scant representation in the MAVM. We cannot correct for this problem without gaining access to the newer data from Guadalajara, Monterrey, Mexicali, and Ciudad Juarez. Until a new dataset is made available with data from these areas, all we can do is indicate those areas where the WB data should be used with care.

[3] Take, for example, the case of Iron and Steel (ISIC 371). Plants located in the MAVM seem to be older than in the rest of the country. Average workers per plant in MAVM is 270, while in the rest of the country is 132 (1994 Industrial Census data). But that figure is much smaller than in Guadalajara and Monterrey, where average plant has 600 workers. Capital per establishment in the MAVM is 3 times smaller that in the rest of the country, and 10 times smaller than in the most important Steel area of Monterrey. Although its not clear for NOX, for PT, SOX and CO, big units are clearly cleaner in 371 INE emissions data, which means that intensities could be severely adjusted if the sample were broader.

Table III.1
Value added share of the MAVM

share of MAVM in national value added	ISIC	branch	share of group in total value added
more than 50%	352	Other Chemicals	11.9
	342	Printing	
	390	Other manufacturing	
between 40 and 46%	355	Rubber	14.4
	354	Coke industries	
	321	Textiles	
	322	Apparel	
	362	Glass	
	312	Other Food products	
between 26 and 40%	356	Plastics	23.2
	341	Pulp and Paper	
	332	Furniture	
	381	Fabricated metals	
	382	Machinery	
	372	Non ferrous metals	
	383	Electronics	
	385	Instruments	
25% or less	384	Transport	50.5
	313	Beverages	
	311	Food products	
	314	Tobacco	
	323	Leather	
	369	Cement	
	351	Petrochemicals and basic chemicals	
	361	Pottery and clay	
	331	Wood Products	
	324	Shoe	
	371	Iron and Steel	
	353	Oil refining	

Source: INEGI, *XIV Industrial Census.*

Size Bias

We question the manner in which the WB created the "overall" coefficients from the coefficients estimated for small, medium, and large sized firms in their sample. As will be shown, the WB calculations under-represent the share of small firms in the Mexican economy. Because small firms are dirtier on average, the WB's overall coefficients are generally cleaner than they should be. In this section we perform a simple analysis that reveals the methodology used by the WB to create their coefficients. We then correct for this mistake and offer a new set of intensities corrected for what we call the "size bias" in the data.

The WB database was constructed with a non-random sample that does not adequately represent the distribution of small firms in Mexican industry. As shown in table III.2, in the WB database, 40.5% of all firms are small. However, according to the Mexican Industrial Census, small firms in the Mexican economy are 93.1 %. This creates a "size bias" away from small firms, and is a function of the reporting requirements for the SNIFF at INE –larger firms are more likely to report through COA. Smaller firms are incredibly numerous and much harder to account for. Indeed, many of them reside in Mexico's "informal economy," that avoids not only environmental, but numerous other federal requirements as well. Because large firms are easier to target, they are subject to higher levels of environmental monitoring.

Table III. 2

Sample size and structure by plants

		INE-World Bank database			1993 Census INEGI		
category	**size (num. of employees)**	**number of plants**	**%**	**workers (% estimated[1])**	**number of plants**	**%**	**workers (%)**
Total		5,799			265,427		
small	20 or less	2,346	40.5	1.7	247,081	93.1	14.7
medium	21 to 100	2,143	37.0	17.0	12,854	4.8	19.6
large	more than 100	1,310	22.6	81.3	5,492	2.1	65.7

Notes:

[1] We estimated the employment share by plant size multiplying the number of plants in the WB sample for the average number of workers by size according to the Industrial Census: 3, 34 and 264 workers for small, medium and large plants.

After learning from the WB that they could not reproduce their methodology, we performed a number of statistical analyses to attempt to determine how they calculated the "overall" coefficients. It is common practice to estimate such coefficients by weighing intensities according the distribution of plants by size in each industrial branch in the Mexican economy. As the intensities are presented in tons per production worker, the normal criteria to create "overall" intensities should be the production worker share of small, medium and large firms. Our hypothesis was that perhaps the WB calculated these data by taking the

weighted average of their sample rather than the employment size distribution of industry in the Mexican economy. Our regression results came close to mimicking our hypothesis in a few cases, but not significantly enough to strongly conclude that we could reproduce the WB methodology. It is evident however, because the WB sample under-represents small firms, that the overall coefficients do not parallel the size distribution of firms in the Mexican economy.

To test how close the WB overall coefficients were to a more realistic plant-size distribution we created new overall intensities, obtaining very different results than the WB's. Our guess is that the WB calculated overall coefficients with a different plant-size distribution, closer to, if not exactly, that of the sample. In this way, we conclude that the overall coefficients provided by the WB have a strong bias against small plants, over-weighting the importance of large plants.

We corrected for the size bias by using the WB coefficients by size to create a new "overall" coefficient. Rather than using the WB methodology, we construct our coefficient by taking the weighted average of the small, medium and large firm coefficients, weighted by the distribution of industry by size in the entire Mexican economy. Thus, our corrections are based on the weighted average of the distribution of production workers in the Mexican economy in the following manner:

$$(1)\ E_{pi} = \Sigma a_{si} * e_{psi}$$

where E_{pi} is the overall coefficient for pollutant *p* in branch *i*; *a* is labor share of plants (measured as the share in direct workers) of 's' size (measured as total employment per plant) in branch 'i'; e_{psi} is coefficient for pollutant 'p' as reported for each size category and branch.

This correction moves the overall coefficients closer to the intensities of smaller plants –usually but not always making the new overall coefficients more pollution intensive than the the WB values. While small plants are more air pollution intensive in general, they are not uniformly so. Table III.3 shows the percentage change from the original to the corrected coefficients. Of course, when the size distribution in the WB sample was closer to the actual distribution as recorded in the Mexican Census there was little change in the coefficient. This is the case in the Pulp and Paper, Other Chemicals, Non-ferrous metals, and Auto sectors. We present the corrected and original overall intensities in the second appendix, but make one final correction to them in the following section.

Table III.3
Change in coefficients corrected for size bias
(percent change)

branch	PT	SOX	CO	NOX	HC
311	-27.9	-13.4	-22.3	-14.8	67.7
312	299.8	19.3	136.9	-40.4	825.0
313	58.5	40.6	10.6	7.8	-11.5
314	-0.7	-0.7	-0.7	-0.7	-0.7
321	-1.4	-1.9	-2.0	-2.1	82.7
322	131.7	93.3	88.3	107.9	60.9
323	13.8	2.0	21.8	6.1	-4.1
324	47.4	87.8	61.7	82.4	43.5
331	80.2	79.7	36.1	49.1	-37.7
332	82.6	60.6	12.1	42.4	-4.0
341	-1.4	-2.0	19.3	-0.8	-2.6
342	-14.3	-30.1	-18.6	-20.6	6.7
351	11.6	-12.6	-11.9	9.6	-28.7
352	-0.4	-2.0	1.3	-1.5	3.1
353	-7.6	0.6	-7.2	-12.7	-41.6
354	-5.5	-15.5	-14.3	-15.3	-10.9
355	28.5	-4.8	-1.4	-3.6	-16.6
361	127.2	74.2	32.9	-25.9	541.1
362	-2.9	-3.5	-2.0	-4.9	15.2
369	45.1	20.4	6.2	41.0	28.4
371	-14.3	-0.3	-14.8	7.2	12.5
372	1.5	1.4	-2.2	1.7	0.7
381	33.9	29.7	5.3	-3.7	3.3
382	-26.0	330.7	184.6	1.5	-17.5
383	1.6	-1.9	2.8	3.2	7.2
384	1.1	4.8	-2.8	-2.7	3.8
385	43.4	7.5	-26.1	9.8	-5.1
390	63.7	2.4	37.7	6.0	4.2

Indicator bias

Another significant flaw with these data is the measure of economic activity used to express pollution intensity. The World Bank chose to create intensities expressed as pollution per employee (although as mentioned earlier it is really pollution per production worker). Although technical papers describing the original IPPS say that the "volume of output would be the ideal unit of measurement," the WB acknowledges that in many countries such data are not available and require a number of conversions that make manipulating the data more difficult (Hettige et al, 1994). Employment data is more prevalent and recommended as a proxy, as has been done with the Mexico coefficients. This poses a problem, particularly for nations such as Mexico which have undergone a great deal of structural change.

It is important to point out that the WB mistook "production workers" (called "obreros" in Spanish), for "employees" in the SNIFF. The WB reports the data as tons per employee but SNIFF's database does not report employees, but only production workers. We attribute this mistake to the lack of adequate knowledge of Spanish and to the lack of actual collaboration with INE. This is particularly problematic for cases when the WB data are used to estimate pollution loads for countries at similar stages of development –multiplying the WB coefficients by employment levels in another country would be incorrect.

Employees do not create pollution, the processes that they operate during production do. Employment levels are not measures of economic performance, and can vary independently from output levels. This can be especially true in countries undergoing great structural change –like Mexico. Indeed, the case of the steel industry in Mexico is a classic case. During transition or crisis firms can shed workers to maintain productivity, without changing production technique in any way that affects emissions. Thus, using pollution per unit of employment as the measure of economic performance can further skew one's picture of pollution because such estimates may be tracking large employment changes rather than actual changes in production. This notion is expressed in equation (2)

$$(2)\ \frac{P}{O} = \frac{P}{Y} * \frac{Y}{O}$$

Where P is pollution, Y is output, and O is workers (obreros). The appropriate measure is P/Y, pollution per unit of output. The WB measure is P/O, pollution per production worker. The ratio between the two is Y/O or worker productivity. If productivity is growing, then constant pollution per unit of output implies growing pollution per worker (or, constant pollution per worker implies falling pollution per unit of output).

As shown in equation (2) it is fairly simple to correct for the indicator bias as well. Using value added and data for workers for Mexico in 1993, one can calculate a productivity measure and then divide that measure by the corrected pollution per worker estimates. This can be expressed as (3):

$$(3)\ \frac{P_i}{Y_i} = \frac{P_i}{O_i} \Big/ \frac{Y_i}{O_i}$$

where: P is pollution; Y is output (in this case the value added of output); O are workers; and i is industry. We corrected the pollution per worker coefficients and express them as pollution per value added production in the appendix. These new coefficients incorporate the correction of the plant size bias as well and are presented in pollution per value added in Pesos and US dollars.

Table III. 4: Illustration of "Indicator Bias" in World Bank Pollution Intensities for Mexico: the Case of the Steel Industry, 1988 to 1993

	SOx (employment method)	SOx (value added method)
1988	19,684.29	12,775.86
1993	8,189.83	14,631.81

Table IV.4 compares the WB employment method with new coefficients corrected for size and indicator biases for Sulfur Oxides in the Mexican Steel Industry. The steel industry in Mexico underwent drastic changes in Mexico in the late 1980s due to privatization and the liberalization of trade and investment regimes. In that process, the steel industry shed over 30,000 workers while productivity increased. Table IV.4 calculated total pounds of SOx in the Mexican industry for 1988 and 1993 using the WB employment intensities and our new coefficients corrected for size and indicator biases. The first column is the result of holding pollution per worker constant for years when employment levels were cut in half –it looks as if total pollution is thus cut in half. However, in the Mexican steel industry the shedding of workers made the industry more productive and it produced slightly more in 1993 than in 1988 –thus in column two pollution rises in step with value added production. Examples like these will not occur for all industries, but the example of steel is a stark one.

Correction results

In order to illustrate the importance of the biases in the World Bank database and the impact of our corrections, we estimate pollution volumes for some important branches using both sets of intensities.

For manufacturing industry as a whole, pollution volumes are slightly smaller using our intensities set than with the World Bank's intensities. For the year 1993, manufacturing as a whole would have produced fewer tons of PT, SOx, CO and NOx, but more of HC. This result is mainly due to the fact that the largest polluter –the food industry, branch 311 was a branch in which our correction significantly reduced pollution intensity. Some branches of growing economic importance are dirtier according to our estimates: Electronics, Fabricated metals, Cement and Apparel, while in other cases the effect is mixed (Steel, Transport and Paper).

Table III.5

Pollution volumes change after correcting intensities
(percent change)

	PT	SOx	CO	NOx	HC
Total manufacturing	-5.0	-0.4	-3.4	-5.4	4.1
383 Electronics	1.6	-1.9	2.8	3.2	7.2
311 Meat and Dairy products	-27.9	-13.4	-22.3	-14.8	67.7
321 Textiles	-1.4	-1.9	-2.0	-2.1	82.7
381 Fabricated metals	33.9	29.7	5.3	-3.7	3.3
371 Steel	-14.3	-0.3	-14.8	7.2	12.5
353 Oil refining	-7.6	0.6	-7.2	-12.7	-41.6
341 Transport	1.1	4.8	-2.8	-2.7	3.8
341 Paper	-1.4	-2.0	19.3	-0.8	-2.6
369 Cement	45.1	20.4	6.2	41.0	28.4
322 Apparel	131.7	93.3	88.3	107.9	60.9

This simple test illustrates the importance of methodological accuracy in these kinds of estimates. While overall intensity is slightly cleaner, Table IV.5 reveals that some of the most dramatic changes come in those sectors most affected by economic integration: apparel, food and beverages, fabricated metals, and electronics.

Unfinished Business

In addition to the three biases described above and corrected for in the appendix, there are a number of errors and inconsistencies with these data that are beyond repair. We will outline these further problems in this section and urge the WB to correct for them in the construction of a third phase of data.

There are a number of other errors in the WB database as presented on their web page, perhaps simply typographical in nature. Large plants in the Shoe industry (code 324) are reported to emit exactly the same amount of PT, CO, NOx, and HC (each is listed at 0.0000717417281682652 units of pollution per employee). The same mistake is repeated for large firms in the Wood furniture industry (code 332), but for only PT and HC. The probability of any industry having precisely the same coefficients for multiple pollutants is essentially zero. These errors for large plants, undoubtedly were overlooked in calculations for overall pollution coefficients as well.

In addition to these errors, there are also inconsistencies between these data and other data reported for Mexico. Most striking is the case of oil refineries. The World Bank database reports pollution coefficients for small and medium sized firms in oil refining (branch 353). According to the Mexican Census, small and medium sized oil refineries do not exist in Mexico. Indeed, to date no technique is known for oil to be refined with less than 100 employees, let alone 20. At the same time, small firm coefficients are missing in sectors where small firms do exist, such as Miscellaneous coal and oil products (354). Perhaps the small and medium-sized "oil refineries" really belong in Miscellaneous coal and oil products (354) or in Industrial chemicals (351). Another intriguing case is the Tobacco industry (314). Since there are no coefficients offered for small or medium firms in the Tobacco industry, one would expect that the overall coefficients would be equal to the coefficient for large firms. However, this is not the case: the overall coefficients for Tobacco are the coefficients for large firms multiplied by a factor of 1.03. We have corrected for this mistake for Tobacco, but it is impossible to do so for coal (324) with the available information.

Finally, as mentioned earlier in the paper, the WB omitted many "outliers" in the data. They omitted the top 25 polluters from the overall dataset, and the top 10 polluters from each plant-size category. There is a strong need for an explanation regarding the rationale for these omissions.

V. Recommendations and Conclusions

With information obtained from Mexico's National Institute of Ecology, the World Bank made an important attempt to go beyond its IPPS approach for environmental statistics in the creation of pollution coefficients that represent actual Mexican industries. However, the World Bank data only represents industry in which is a relatively small percentage of total industrial production in Mexico. In addition, a number of errors were made in creating and presenting the data –most notably mistaking "production workers" for "employees," and misrepresenting the size distribution of Mexican industry. Finally, after the coefficients were constructed, they were presented in terms of pollution per employee, an expression that does not lend itself to solid economic analysis. In addition to pointing out these shortcomings, we have corrected for the size and indicator biases in the data and present them for the larger research community.

The problems with these data point out the need for two way collaborations in international research. According to our interviews, the World Bank simply obtained pollution data from INE and proceeded to create intensities for their own ends. A more engaged collaboration with INE might have avoided the problems associated with the distinction between "obreros" and "empleados," the problem of regional representation of the firms in the sample, and in the size bias.

We are fully aware that some of our conclusions could be wrong. They are made on the basis of interviews with senior members of INE, and the analyses that we have presented

here. Nevertheless we feel that we have raised enough questions to ask for disclosure of the methodology used to create these coefficients, and the construction of a new database on Mexican industry.

Based on our research, in addition to disclosing the process by which the data were created, we propose that the three improvements be made in a future dataset:

1) Construct truly "national" coefficients for pollution in Mexican industry. INE has embarked upon an ambitious effort that has resulted in the creation of pollution estimates for industry in the Guadalajara, Monterrey, and Northern Border regions. Such data could be used to round out the distribution of Mexican industry in the World Bank sample.

2) Construct data that is more suitable for economic analysis. This is a task that could be carried out at both INE and the World Bank. Since much of these data is based on plant level interviews, INE surveyors could incorporate economic questions into their calculus. Most important would be information regarding the level of value added production, and employment in each firm.

3) Compile and publish coefficients over time. As we have shown, having coefficients for only one point in time forces researchers to assume that technology remains constant. INE compiles these data over time. Indeed, they began such efforts in the late 1980s. Calculating intensity coefficients over time can allow for better monitoring of the successes and failures of environmental policy.

In the meantime, we have corrected some of the more serious errors with these data and offer them to the research community interested in these issues in the appendix. These new coefficients can be used, with a higher degree of confidence than those presented by the World Bank, until better data become available.

VII. References

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Appendix

Below are the original and corrected intensities for industrial air pollution in Mexico. They can be downloaded from:

PROCIENTEC:
http://www.colmex.mx/informacion_academica/centros/cee/procientec/index.htm

Table A1
Corrected coefficients (overall)
Tons per worker

ISIC3	PT	SOX	CO	NOX	HC
311	0.1470957041740510	0.1447012466142680	0.0962771572020825	0.0678634755943334	0.0048870666024567
312	0.1203231591277860	0.0460426782617396	0.0382367390920563	0.1342661267481240	0.0804940104755762
313	0.0768726331380669	0.1695825708166160	0.0097716106433249	0.1294752284991270	0.0776230702953444
314	0.0068611384111811	0.0393006032712896	0.0130087188806133	0.0075198082968477	0.0001646673274301
321	0.0140845487423919	0.0615246443798262	0.0578426561330750	0.0429549651235909	0.0158857491658781
322	0.0014811301721328	0.0054153796341461	0.0018166323608463	0.0022953609257216	0.0068448324104875
323	0.0135887940838427	0.0542376232685642	0.0040612723630085	0.0227270572488672	0.2305904946562560
324	0.0002273496754414	0.0029339959882719	0.0003430267943623	0.0008442943120802	0.0048158754046068
331	0.1960832416839390	0.0355435576921854	0.0011132034776002	0.0070675489666734	0.1522596473403270
332	0.0035856167975153	0.0026863813385903	0.0017931575730792	0.0013463397972983	0.0600578217554276
341	0.0506702144309741	0.5194876518558800	0.0388345113262930	0.1564759814931720	0.0452219635959190
342	0.0009082774185995	0.0006352761001981	0.0016240506012917	0.0007493492649632	0.3636883219376370
351	0.1298072942140650	0.1674994947344120	0.0333081066246118	0.1399173533776880	0.0405945356328383
352	0.0168134349220197	0.0561601001569799	0.0042249237220075	0.0310959115316515	0.0620848945505331
353	0.0248816937228874	0.1430539331808490	0.1351508729096310	0.6794616024502620	0.0112194654372348
354	0.2624886898057740	1.7379957371700300	0.0276320842488060	0.4481884673833080	0.0047490220555438
355	0.0178578150575884	0.0860286767445080	0.0053953508500565	0.0345028868546486	0.0187817344086330
361	0.0057668385467564	0.0156335735134781	0.0329603138503948	0.0438641819965034	0.0136599582294768
362	0.0316267096759804	0.1688837439631510	0.0205708140297317	0.2045667265414200	0.0025620829550949
369	0.0751515020508493	0.0690283856200718	0.0103149625246447	0.0911280858476352	0.2228176663594290
371	0.0716418852462528	0.3358691886613990	0.2265110274772880	0.0917468374687198	0.0298207614670840
372	0.0846144815208615	0.1764484286861640	0.0768335242517489	0.2078614683213580	0.0121260286206205
381	0.0182883061873737	0.0169192067342637	0.0571023758717967	0.0202524459825681	0.0488902377711359
382	0.1033879809146760	0.0493453198362137	0.0404912963554640	0.0414776712645705	0.0274486290711413
383	0.0222352383440236	0.0009574498071796	0.1645645921402610	0.0300382624932007	0.0413723627309609
384	0.0043654937187140	0.0101611367956732	0.0427285751665778	0.0689230474766878	0.0216187592509561
385	0.0017657554272645	0.0012800149816153	0.0542975462853163	0.0006764054841232	0.0231035474332386
390	0.0030704974860996	0.0042070368495619	0.0017523327879269	0.0032144889346898	0.0258419130333776

Table A2
Original coefficients (overall)
Tons per worker

ISIC3	PT	SOX	CO	NOX	HC
311	0.20396350411864100	0.16712214785097300	0.12388038079689100	0.07967967423414490	0.00291332998493169
312	0.03009715529643730	0.03860481438249410	0.01614354486603710	0.22527965206057800	0.00870196988696082
313	0.04849567021878940	0.12059524039432800	0.00883116857800498	0.12011904651729200	0.08771644859180970
314	0.00690925801846356	0.03957623239900040	0.01309995365919800	0.00757254739062460	0.00016582219804393
321	0.01428108367142570	0.06268812245903890	0.05900671391662280	0.04387473889125650	0.00869645772130505
322	0.00063934901215524	0.00280151121548577	0.00096483578414496	0.00110433011551323	0.00425457709301907
323	0.01193569979349080	0.05316811827200420	0.00333556589749701	0.02141995985268030	0.24052244057031700
324	0.00015426642753372	0.00156194755363633	0.00021211633785886	0.00046279928379842	0.00335529481562008
331	0.10883072473019900	0.01978318065587200	0.00081771720747138	0.00473904292710300	0.24459036994498700
332	0.00196363630168366	0.00167272722630790	0.00159999995972171	0.00094545452432199	0.06254538003693930
341	0.05141194533291490	0.53031694370204700	0.03255367012428030	0.15769010470851200	0.04640775865786710
342	0.00106005494507497	0.00090861852118950	0.00199539747655228	0.00094425059132105	0.34081211284374900
351	0.11627948439410100	0.19155880533966300	0.03779341065777390	0.12763011290966200	0.05693267538405980
352	0.01687601964649990	0.05730016366810750	0.00417074498963384	0.03157150587841840	0.06022294723874950
353	0.02692966340513430	0.14213654984891100	0.14569775947281700	0.77839419774545100	0.01920473410494900
354	0.27785267035968400	2.05707371959653000	0.03223410763004350	0.52935621679490800	0.00532795151114825
355	0.01389961402865320	0.09039161684846680	0.00547159410017250	0.03580800881552810	0.02252620044910070
361	0.00253872300910193	0.00897619887358925	0.02479788413307200	0.05920664978491210	0.00213071396261240
362	0.03256804918528390	0.17497811360173900	0.02099371777880620	0.21509232856458500	0.00222349128196503
369	0.05177686005938520	0.05735537142315800	0.00971074386297138	0.06462809871805230	0.17353306381165300
371	0.08362430848359620	0.33678453349084700	0.26592264469939400	0.08554696085113300	0.02649723827482150
372	0.08338607821363050	0.17409316377420800	0.07853048523430900	0.20440853262322700	0.01204381980182480
381	0.01365764321148060	0.01304641457696310	0.05425284887725690	0.02104046235088470	0.04732100961921020
382	0.13976544087524300	0.01145612958116570	0.01422809246926890	0.04084616654132000	0.03325697410882950
383	0.02188814149173160	0.00097560975008718	0.16003363467006200	0.02911900759384530	0.03858073928999420
384	0.00431744567360358	0.00969689957063157	0.04397269746395820	0.07082600787482530	0.02083525914867200
385	0.00123161135360553	0.00119055765787706	0.07344509479967320	0.00061580566533249	0.02434485150278740
390	0.00187576458058604	0.00411037104911935	0.00127225767416492	0.00303384530324723	0.02479271428471950

A 3 :Mexican Pollution Intensities in Tons per thousand 1993 Pesos (Corrected for size and indicator bias)

3 digit ISIC	PT	SOX	CO	NOX	HC
311	0.00197237640615234	0.00194026961130766	0.00129096083657286	0.00090996755380006	0.00006552968297820
312	0.00060779841455248	0.00023257922292013	0.00019314843099430	0.00067822969042015	0.00040660611226196
313	0.00049636608608170	0.00109499354331643	0.00006309522559257	0.00083602069801900	0.00050121165386574
314	0.00000754575973429	0.00004322211445474	0.00001430676095443	0.00000827015332667	0.00000018109823974
321	0.00027759929769669	0.00121261947281799	0.00114004935572583	0.00084662053211580	0.00031310004264181
322	0.00005394964364450	0.00019725329141136	0.00006617019242785	0.00008360771140046	0.00024932060415756
323	0.00037816520084801	0.00150938939616895	0.00011302194067991	0.00063247570874750	0.00641714784897726
324	0.00000770630728516	0.00009945153699975	0.00001162733080338	0.00002861843279683	0.00016324024058040
331	0.00706358742644459	0.00128040022721734	0.00004010138765518	0.00025459722915661	0.00548491202650346
332	0.00009736390325270	0.00007294604736669	0.00004869143311218	0.00003655853516200	0.00163081117620143
341	0.00060627057494289	0.00621568471543457	0.00046465604643318	0.00187223962499413	0.00054108209679462
342	0.00000946303909912	0.00000661872953330	0.00001692044085238	0.00000780721974149	0.00378914717014016
351	0.00059022472239248	0.00076160853193247	0.00015144964006037	0.00063619445698521	0.00018458052507459
352	0.00007035666727863	0.00023500477442028	0.00001767940661534	0.00013012241172046	0.00025979737568081
353	0.00005313411547504	0.00030548741132512	0.00028861066162577	0.00145097000419374	0.00002395883410308
354	0.00180497803421502	0.01195115923460350	0.00019000934914788	0.00308192455611690	0.00003265618987470
355	0.00022391427402868	0.00107869012176317	0.00006765083325281	0.00043262229097111	0.00023549904686248
361	0.00009898301663420	0.00026833736623458	0.00056573654137711	0.00075289242468002	0.00023446189132715
362	0.00029516995695026	0.00157618063800870	0.00019198602553965	0.00190920751748469	0.00002391174811753
369	0.00057553872060136	0.00052864557142281	0.00007899589725390	0.00069789346198445	0.00170642224206133
371	0.00046754531148655	0.00219193093386164	0.00147824374711783	0.00059875313937892	0.00019461460514292
372	0.00068203275132137	0.00142225781119378	0.00061931455463942	0.00167546177184768	0.00009774152738482
381	0.00032717783025588	0.00030268463860195	0.00102156160602170	0.00036231629468921	0.00087464644077853
382	0.00162678838272291	0.00077643834748594	0.00063712212899119	0.00065264253309376	0.00043189847117195
383	0.00047718298590273	0.00002054750890335	0.00353166546885525	0.00064464106775307	0.00088787838818543
384	0.00003380790805916	0.00007869139224552	0.00033090500956123	0.00053376415186673	0.00016742322225233
385	0.00004482969046137	0.00003249752175511	0.00137852737428848	0.00001717284738951	0.00058656191225541
390	0.00006097991088115	0.00008355152001309	0.00003480123260991	0.00006383957311582	0.00051321896888294

A 4: Mexican Pollution Intensities in Tons per thousand 1993 Dollars (Corrected for size and indicator bias)

3digit ISIC	PT	SOX	CO	NOX	HC
311	0.00614516953402896	0.00604513705701322	0.00402213957629310	0.00283511041357238	0.00020416539670426
312	0.00189366709533157	0.00072462778934018	0.00060177654224077	0.00211310397834981	0.00126682893063829
313	0.00154648663429553	0.00341158053876398	0.00019658055979819	0.00260472032988169	0.00156158356783655
314	0.00002350969758391	0.00013466355616254	0.00004457438817134	0.00002576663060167	0.00000056423276107
321	0.00086489310131293	0.00377805788869075	0.00355195719551443	0.00263774535358114	0.00097549982708373
322	0.00016808642886915	0.00061456571528996	0.00020616097885785	0.00026048961004875	0.00077678752194340
323	0.00117821794249432	0.00470267931789862	0.00035213308391673	0.00197055209354816	0.01999337516606290
324	0.00002400990226861	0.00030985290301430	0.00003622630994375	0.00008916407678887	0.00050859407464681
331	0.02200743332689450	0.00398923676186585	0.00012494056657857	0.00079322746468735	0.01708888535523010
332	0.00030334863574536	0.00022727194794431	0.00015170385855147	0.00011390239499188	0.00508098308440876
341	0.00188890693221441	0.01936569319490630	0.00144769029452839	0.00583318167264019	0.00168580459909131
342	0.00002948320583730	0.00002062142649604	0.00005271761379019	0.00002432430683679	0.01180553147830490
351	0.00183891420063806	0.00237288051747585	0.00047185907879227	0.00198213828891324	0.00057508222858747
352	0.00021920443122715	0.00073218487891775	0.00005508226045160	0.00040541160282830	0.00080942912979213
353	0.00016554555541036	0.00095178178325842	0.00089920029436898	0.00452066686498003	0.00007464655171388
354	0.00562362031448522	0.03723523532107290	0.00059199636536010	0.00960209665323007	0.00010174418153123
355	0.00069763112695080	0.00336078532081419	0.00021077408863748	0.00134788538025744	0.00073372484255948
361	0.00030839317298131	0.00083603646985571	0.00176261840666585	0.00234572446522538	0.00073049346310378
362	0.00091963654663151	0.00491077524888488	0.00059815493200258	0.00594835946829909	0.00007449984981512
369	0.00179315824325488	0.00164705714876406	0.00024612096332308	0.00217436876004368	0.00531655820937394
371	0.00145669213795255	0.00682921736107093	0.00460564140309215	0.00186548548189810	0.00060634457939717
372	0.00212495285968571	0.00443121066730490	0.00192954697758482	0.00522009724090836	0.00030452516792490
381	0.00101936082201484	0.00094304941681178	0.00318279474388187	0.00112883882045101	0.00272506335208307
382	0.00506844960051148	0.00241908454346713	0.00198502855961965	0.00203338419505991	0.00134563023495959
383	0.00148671944055892	0.00006401816880348	0.01100331710311240	0.00200845469332496	0.00276628903285434
384	0.00010533249432834	0.00024517224233117	0.00103097328535786	0.00166300468519948	0.00052162664360858
385	0.00013967214735679	0.00010124983243463	0.00429496337305518	0.00005350401589746	0.00182750228697235
390	0.00018999004924503	0.00026031453920493	0.00010842731322175	0.00019889966162295	0.00159899376307060

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