Small Plants, Pollution and Poverty:
New Evidence from Brazil and Mexico

by

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1. Introduction

Small enterprises are controversial in the literature on environment and development. Noting that pollution from large factories may overwhelm environmental absorptive capacity, Schumacher (1989) touts small plants as the agents of choice for sustainable development. In contrast, Beckerman (1995) argues that small factories are pollution-intensive, costly to regulate and, in the aggregate, far more environmentally harmful than large enterprises. Recent policy reports from the World Bank and other international institutions have tended to side with Beckerman, at least in noting the potential gravity of the small enterprise pollution problem (EA2, 1997; ENV, 1997).

Controversy over the role of small enterprises in development extends well beyond environmental questions. Desoto (1989) depicts small enterprises on the leading edge of free enterprise, thriving in the shadows of ossifying state-owned factories and protected monopolies. In contrast, some countries (such as India) have deemed it necessary to protect small enterprises from the competition of larger plants, partly because small enterprises are viewed as important, but threatened, sources of employment for the poor and unskilled. Certainly the small scale sector often provides a haven from the taxation, regulation and collective bargaining which pervade the larger industrial plants in many economies.

It may well be true that some small enterprises are dynamic while others are stagnant; that some are environmentally benign while others are highly-polluting. For policymakers, however, it is important to know whether one story dominates the others. If small enterprises are generally clean, then environmental concerns are misplaced. If they are dirty but stagnant, then economic growth will diminish their role over time. If they are dirty and fast-growing, on the other hand, there is cause for concern because small plants are difficult and costly to regulate.

This paper presents some new empirical evidence on a series of related questions:

1. Are small plants more pollution-intensive than large facilities?
2. Is the share of small enterprises in industry lower in higher income regions?
3. Is industry less pollution intensive in higher income regions?
4. Do poor areas suffer more from industrial pollution in total, from small plants and from large plants?

The data for this analysis are drawn from large databases on enterprises in Brazil and Mexico. These data are described in Section 3 after a brief review of the relevant theoretical and empirical literature in Section 2.

The analysis in this paper focuses on air pollution because this poses the most serious threat to human health, and Sections 4 and 5 summarize the results. We believe that this evidence provides the first systematic assessment of the relationships linking economic development, the distribution of plant sizes and industrial pollution, and the paper accordingly draws together both a summary and some broader implications in closing.

2. Development, Pollution and Small Enterprises: Previous Research

In this section three aspects of existing research are reviewed:

whether small enterprises are more pollution intensive, with higher emissions relative to their size;

the relative role of smaller enterprises in production as development proceeds;

the share of dirty industries in industrial production in poor regions.

Together these three form key aspects of whether lower income persons are exposed to greater industrial pollution harm. However these three do not represent the entire story as will become apparent in later sections.

2.1 The Pollution Intensity of Smaller Enterprises.

There are good reasons to assume the worst about small plants in pollution-intensive sectors. Many operate with unskilled labor in highly-competitive, unregulated markets, so it seems unlikely that they would be willing, able or effectively required to control pollution. However, Blackman and Bannister (1996) find that small-scale brickmakers in Ciudad Juarez, Mexico have responded significantly to informal community pressure for improved environmental performance. Recent research has suggested that such 'informal regulation' is common in developing countries (Pargal and Wheeler, 1996; Hettige, Huq, Pargal and Wheeler, 1996). As a result, it is not self-evident what the outcome is likely to be with respect to relative emission intensity of smaller enterprises within specific sectors. Moreover, at least some of the most pollution intensive industries — steel, paper and industrial chemicals for instance -- also exhibit important scale economies. Thus it is even less evident whether smaller enterprises are likely to be pollution intensive in the aggregate, irrespective of sector.

Recent empirical research has suggested that plant size is inversely correlated with emissions intensity (emissions/output) in developing countries, because of private scale economies in pollution control and public scale economies in regulatory monitoring and enforcement.[1] However, problems of data availability have limited most empirical research to analyses of medium- and large-scale industrial water polluters.[2] Little work has been done on problems related to air pollution in general and on emissions by small plants in particular

2.2 Development and the Role of Small Enterprises

The same uncertainty surrounds the effect on the small enterprise sector which may be anticipated from economic development. Theoretical work has focused on the problem of optimum scale, defined by Saving (1961) as 'that size of plant or firm that has minimum average costs of production in the light of its total economic environment.' The latter includes demand conditions, factor supply

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[1] Dasgupta, Huq, Wheeler and Zhang, 1996; Pargal and Wheeler, 1996; Hartman, Huq and Wheeler, 1996; Dasgupta, Hettige and Wheeler, 1998; Hettige, et. al., 1996

[2] Industrial water pollution has traditionally been the first focus of regulation in developing countries. Water pollution is also easier to measure than air pollution. For both reasons, the available data are much more plentiful for water polluters.

conditions, taxes, and subsidies, all of which may differ by location. Scale economies may also differ by sector. In consequence, optimal scale may be highly variable. This conclusion is buttressed by Lucas (1978) and Oi (1983), who attribute broad size ranges to ability distributions of principals or managerial agents.

Not surprisingly then, under varying assumptions about demand and technology, Mills (1990) finds that nearly any sequence of plant types can emerge in equilibrium. As a corollary, Mills finds no theoretical support for a monotonic relation between industrial growth and average plant size. Under plausible assumptions, his numerical simulations show that small plants can either precede or follow large plants in a growing industrial economy.

Since the theory is inconclusive, empirical work is necessary to show whether small plants occupy the leading or trailing edge of economic development. However, relevant studies are rare. Little (1987, pp.229-230) notes that "cottage shop manufacturing still accounts for over half of manufacturing employment in poorer countries (India, Indonesia, the Phillippines, and most of Africa). There has also been a relative fall in employment in small-to-medium size factories in the more rapidly industrializing economies (Colombia, Korea, Malaysia, Singapore, and Taiwan)." However, this pattern is not inevitable, for Little goes on to note (p.230) that "the relative decline of small-scale enterprises in most developing countries ... has been accelerated by the industrialization policies adopted in these countries .. In most countries there have been countervailing measures in support of [small enterprises]. But these have only scratched the surface...". Where such countervailing policies are more substantial (notably in India) the role of small enterprises has actually increased.

In the absence of policy intervention, whichever plant sizes are more efficient in purely private terms will tend to dominate. Certainly among the developing economies, much of the attention has focused on whether small enterprises are more or less efficient than larger plants (either in terms of private costs or in social terms incorporating, for instance, a concern for employment creation). However, the evidence is mixed. Little (1987) leans toward the middle size enterprises being the most efficient, for example, while in a recent contribution on Philippines manufacturing, Mini and Rodriguez (1998) support a monotonically increasing relationship between plant size and economic efficiency. Moreover the picture is complicated by the fact that numerous studies have shown small factories with higher average costs can co-exist with large plants in competitive markets. Caves and Pugel (1980) identify market strategies uniquely available to small firms. Mills and Schumann (1985) argue that superior output flexibility sustains small firms in competition over the business cycle. Mills (1990) draws on earlier work by Manne (1967) and Gilbert and Harris (1984) to show why high-cost small enterprises can survive in growing sectors with uncertain, fluctuating demand. If installed production capacity is permanent and product-specific, then competitive investment games in uncertain environments involve tradeoffs between scale economies and capacity holding costs. The ability of small plants to come online more quickly may outweigh their scale-related cost disadvantage in such cases.

Despite these ambiguities, the limited available evidence does provide a fairly uniform picture of rising plant scale as development proceeds, even though concentration tends to decline with development. (Banerji 1978, Little 1987).

2.3 Dirty Industries and Poor Regions

The sectoral composition of industry is a key determinant of environmental quality, because some industrial processes are much 'dirtier,' or more emissions-intensive, than others. For example, the wood pulping and metals sectors generate far more emissions per unit of output than sawmilling and electronics. Emissions abatement requires factor inputs subject to diminishing returns, so cost-minimizing firms in dirty sectors should have higher emissions intensities, *ceteris paribus*.

At least three factors may lead to dirty industries having a disproportionate share of industrial activity in poor regions.

> The first has to do with transport costs. Most dirty sectors transform bulk raw materials into semi-finished products, producing large volumes of waste residuals in the process. Examples are provided by metals smelters, pulp mills, sugar mills, and chemical processing facilities. Transport cost considerations frequently dictate that such 'weight-reducing' industries locate

near extraction sites for heavy raw materials. Wages are often low in these areas, so poverty and dirty production will reveal a natural, if accidental, spatial correlation.

Second, recent research suggests that pollution and labor are complements in production (Lucas, 1997; Hettige, Mani and Wheeler, 1998). Dirty industry should therefore have a tendency to locate in low-wage regions.

Third, a number of recent contributions indicate that pollution regulation is weaker in poor regions (Pargal and Wheeler, 1996; Wang and Wheeler, 1996; Dasgupta, Mody, Roy and Wheeler, 1996). This is partly because the poor assign lower relative value to ambient quality, and partly because low-income communities may be poorly-informed or unable to regulate pollution effectively. Weaker pollution regulation lowers the 'price of polluting' for emissions-intensive industries, providing an incentive to locate in poor regions.

2.4 Summing Up: Three hypotheses

From this brief review of prior research it may be fair to extract three null hypotheses to bring to the data:

1: Small plants are more pollution-intensive than large plants in developing countries.

2: The small-plant share of industrial activity falls during the process of economic development.

3: The share of dirty sectors in industrial activity declines with economic development.

3. Data

Two cross-sectional data sets are deployed in the following sections to explore these hypotheses -- one from Brazil the other from Mexico.

3.1 Mexico

The SNIFF (Sistema Nacional de Informacion de Fuentes Fijas) database, maintained by the Instituto Nacional de Ecologia (INE) in Mexico's Environment Ministry (SEMARNAP), records emissions of conventional air pollutants (particulates, SO_2, etc.), sector of production and number of employees for approximately 6,000 plants. These data are unusually rich in covering very small manufacturing plants as well as medium and large facilities. In fact three classifications of plant size, according to level of employment, are distinguished here:

	Range of employment	Number of plants in sample
Small	1-20	2346
Medium	21-100	2143
Large	101+	1310

Research on industrial emissions must consider some subset of pollutants, because factories discharge hundreds of waste products which are potentially harmful to human health or ecosystems. In this paper, we focus on emissions of airborne suspended particulates from the Mexico data base. Environmental scientists generally agree that air pollution from fine particles (those with diameters less than 10 microns) has the greatest impact on morbidity and mortality. Although fine particulate emissions are not yet commonly measured in developing countries, they are known to be highly correlated with total particulate emissions on which the present study focuses.

3.2 Brazil

Although the Mexican data are very rich, no information on plant location is available. Thus it is not possible with these data to explore hypotheses relating to local levels of development. The Mexican data are therefore supplemented by a database of 156,000 factories in 5,000 Brazilian municipios, made available by the Instituto Brasileiro de Geografia e Estatistica (IBGE). The factories in this database are categorized by 266 4-digit Classificacao Nacional de Atividades Economicas (CNAE) codes, employment size, and location. Of the 5000 municipios, 3455 report some industrial employment and these form the data base for the Brazilian analysis.

Information on total population for each municipio is drawn from the 1991 demographic census. To separate Brazilian municipios into ten income classes, median wage of the head-of-household from the same source is used for each municipio. It should, however, be noted that the deciles are constructed from a ranking of municipios by this measure, regardless of population. As a result, the two highest deciles contain half the sample population. No wage data are available for 271 of the

3455 municipios reporting industrial employment and these municipios are therefore excluded from the analysis.

In the ensuing analysis, emissions for the Brazilian plants are imputed according to pollutants per employee, within a specific sector, for plants in a given size category, from the Mexican data base. To achieve this matching, both the Mexican and Brazilian data are first aggregated to the 3-digit level of International Standard Industrial Classification (ISIC).

4. Results: Pollution Intensity, Scale and Dirty Sectors

The results from the Mexico data are presented first in this section, followed be the results of applying the Mexican emission intensity measures to the Brazilian plant data.

4.1 Scale and Pollution Intensity: Evidence from Mexico

The first empirical exercise measures the relative air pollution intensity of small and large plants in the Mexican database. Intensities are computed as particulate emissions per unit of labor, because comparable output data are not available.[3] Using the sample of 6,000 plants, the logarithm of emissions per employee is first regressed on logarithm of actual plant level employment, with dummy variables to control for sectoral differences. The estimated elasticity of emission intensity with respect to employment is -.65, with an extremely small standard error (the t-ratio for a zero null hypothesis is 34.19). In other words this suggests that plant-level emissions per unit of labor decline by .65% for each 1% increase in employment.

Table 1 shows the average emission intensity for each sector and plant size category. While the general pattern is consistent with a negative relationship between pollution per employee and plant size, it also reveals substantial variation. Indeed in some sectors (such as basic foods, petroleum products and industrial chemicals), large plants are more pollution-intensive than small ones.

[3] If small enterprises are more labor-intensive (per unit of output) than large facilities, then a negative relationship between plant size and the pollution/labor ratio implies that pollution/output declines more rapidly than labor/output.

Table 1: Annual Particulate Emission Coefficients (tons/employee)

	Large	Medium	Small
Basic Foods	0.226	0.103	0.018
Other Foods	0.011	0.213	0.248
Beverages	0.046	0.019	0.538
Tobacco Products	0.007		
Textiles	0.014	0.017	0.010
Apparel	0.000	0.001	0.007
Leather Products	0.008	0.010	0.027
Footwear	0.000	0.001	
Wood Products	0.088	0.053	0.525
Furniture	0.001	0.001	0.009
Paper	0.053	0.049	0.027
Printing	0.000	0.002	0.001
Industrial Chemicals	0.139	0.069	0.060
Other Chemicals	0.015	0.023	0.016
Petroleum Refining	0.025	0.040	0.087
Petroleum Products	0.319	0.166	0.221
Rubber	0.010	0.010	0.084
China and Pottery	0.002	0.007	0.011
Glass	0.034	0.031	0.005
Other Non-metallic	0.004	0.139	0.091
Iron and Steel	0.062	0.123	0.248

Non-Ferrous	0.088	0.040	0.022
Metal Products	0.011	0.011	0.042
Machinery	0.147	0.021	0.086
Electrical Apparatus	0.023	0.009	0.010
Transport Equipment	0.004	0.003	0.007
Professional Equipment	0.000	0.002	0.021
Other Manufacturing	0.001	0.003	0.010

Source: SNIFF (INE/SEMARNAP)

Emissions intensity is measured so far by the physical volume of emissions per employee. A true measure of pollution intensity, however, must also consider the impact of emissions on air quality. Technical models of atmospheric dispersion treat large and small facilities separately, because of differences in average stack heights. Large plants have higher stacks, producing substantially lower pollutant concentration per unit of emissions. The standard dispersion model used for World Bank project analysis[4] implies that each unit of particulate emissions from a small plant increases air pollution approximately 14 times more than a unit of emissions from a large facility because of the difference in stack size. In combination with the broad pattern noted in the regressions, and even relative to almost all of the sector specific patterns in Table 1, this implies much greater pollution per employee for small plants.

4.2 Small Plants, Dirty-Sector Location and Level of Development: Evidence from Brazil

Numerous studies have identified six industry sectors as exceptionally pollution-intensive: Iron and Steel, Petroleum and Coal Products, Metal Products, Pulp and Paper, Chemicals, and Food Products (Robison 1988, Tobey 1990, Mani 1996, Mani and Wheeler 1997). In this section, the industry share

[4] This model is embedded in the environmental Decision Support System (DSS), which is available at the Website: http://www-esd.worldbank.org/pollution/dss

(alternatively measured by employment share or fraction of facilities) of these six sectors in each Brazilian municipio is used as a proxy for the concentration of dirty industry.

The Brazilian data suggest that the share of these six dirty industries -- no matter whether based upon share of employment or share in number of enterprises — declines smoothly across deciles. This may be seen in columns 1 and 2 of Table 2, which show the share of the dirty six industries falling from about 55% in the poorest regions to 30-35% in the richest.

Table 2: Pollution Intensity and Plant Scale by Income Decile

	Dirty Industry Share		**Small Plant Share**		**Large Plant Share**	
	No. Plants	**Employ ment**	**No. Plants**	**Employ ment**	**No. Plants**	**Employ ment**
Income Decile	N_6/N_T	E_6/E_T	N_S/N_T	E_S/E_T	N_L/N_T	E_L/E_T
1	0.56	0.55	0.90	0.83	0.06	0.10
2	0.55	0.56	0.85	0.71	0.08	0.16
3	0.51	0.51	0.85	0.67	0.05	0.16
4	0.45	0.46	0.84	0.63	0.06	0.18
5	0.44	0.46	0.83	0.60	0.06	0.21
6	0.43	0.44	0.82	0.55	0.06	0.23
7	0.37	0.39	0.80	0.46	0.06	0.28
8	0.34	0.37	0.75	0.35	0.08	0.36
9	0.33	0.40	0.74	0.31	0.09	0.45
10	0.30	0.35	0.63	0.19	0.16	0.62

N_6 = Number of 'dirty six' plants
N_T = Total number of plants
N_S = Number of small plants
N_L = Number of large plants

E_6 = Employment in 'dirty six' plants
E_T = Employment in all plants
E_S = Employment in small plants
E_L = Employment in large plants

Columns 3-6, in Table 2, present shares by decile for small, medium and large plants again based upon both employment shares and fraction of plants. Small industry clearly dominates the poorest regions of Brazil.[5] In the lowest-decile areas, 90% of manufacturing facilities are small plants. This declines to 63% in the highest-income municipios. The small-plant employment share drops steadily from 83% in decile 1 to 31% in decile 9, and then plummets to 19% in decile 10. The share of employment in large plants climbs steadily through 45% in decile 9 before jumping to 62% in the highest-income municipios.[6]

5. Results: Total Emissions and Health Damage

The results in Section 4 are consistent with the three hypotheses at the end of Section 2. The Mexican data, especially combined with the air dispersion parameters, show that small plants are far more pollution-intensive than large ones. In Brazil, small plants play a much larger role in the industrial economies of poor regions. Furthermore, these poorer regions of Brazil exhibit a greater concentration of plants in the dirtiest sectors. In contrast to poor areas, Brazil's richest municipios are the heartland of large enterprises in relatively clean sectors.

Yet, paradoxically, confirmation of these hypotheses does not imply that pollution damage is actually greater in poor regions. Economic development also promotes two countervailing trends. The first is an increase in the *scale* of industrial activity, which may lead to greater pollution even if production shifts toward larger plants in cleaner sectors. The second is *urbanization*, which increases the size of populations exposed to industrial pollution. A larger exposed population will suffer greater aggregate health damage from pollution, even if industrial emissions remain constant. In this section,

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[5] The database provided by IBGE is more comprehensive than any comparable information source we have seen. Nevertheless, it is entirely possible that small enterprises are undercounted in the database. For this exercise, what matters is the effect of income level on the propensity to undercount. Data-gathering is probably less efficient in poor regions, so undercounting of small plants should be more serious there. Thus, the results in the text probably *underestimate* the decline in small enterprise share as income increases.

[6] These correlations are not just an artifact of Brazil's separation into poor and rich regions. Regressions for the municipios of Rio de Janeiro and Sao Paulo States reveal similar relationships between dirty-sector share, industry scale and development.

these two effects are examined in turn.

5.1 Total Emissions by Income Decile

Total industrial emissions are estimated here in three steps.

> First, total industrial employment, by sector and plant size class, in each municipio, is obtained by summing across individual plants in the Brazilian data set.
>
> Second, total employment within each sector-plant-size category is multiplied by the relevant pollution intensity (emissions per employee) computed from Mexico's SNIFF database.
>
> Finally, emissions are aggregated across Brazil's municipios by income decile.

Columns 2-5 of Table 3 record the resulting estimated total emissions by decile; columns 6-8 tabulate emissions shares by size class; and columns 9-11 show the estimated share of total emissions by plant size and income decile.

Table 3 presents a striking contrast to the information in Table 2. It shows that most of Brazil's industrial emissions are in relatively affluent municipios, and most of the emissions in all income deciles come from large plants. Municipios in the top two income deciles account for about 68% of total emissions. The large-plant emissions share is always high, varying from a low of 67% to a high of 93%.

Inspection of columns 6-8 of Table 3 shows that the variations in shares are not random. The small- and medium-plant shares are quite small in the first three income deciles; rise to a peak in the sixth decile; and decline sharply in the top deciles. Column (5) suggests that most of this variation is due to large fluctuations in emissions from large facilities. While emissions from small and medium facilities display a steady upward trend, large-plant emissions fall sharply from the second to the sixth deciles before increasing to very high levels in the ninth and tenth deciles. Table 3a shows why this occurs: large-plant employment in the middle of the municipio income distribution is simply lower than in the tails. This translates to the observed discontinuity in emissions.

Table 3: Industrial Emissions by Plant Size and Income Decile

	Total Particulate Emissions (Tons/Year)				% Share by Income Decile			% Share of Total Emissions		
Income Decile	**Small**	**Medium**	**Large**	**Total**	**Small**	**Medium**	**Large**	**Small**	**Medium**	**Large**
	(2)	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**
1	219	200	3,112	3,531	6.2	5.7	88.1	0.1	0.1	1.4
2	319	389	9,825	10,532	3.0	3.7	93.3	0.1	0.2	4.5
3	464	728	8,133	9,324	5.0	7.8	87.2	0.2	0.3	3.7
4	565	664	5,801	7,030	8.0	9.4	82.5	0.3	0.3	2.7
5	757	962	4,656	6,375	11.9	15.1	73.0	0.3	0.4	2.1
6	906	1,107	4,134	6,146	14.7	18.0	67.3	0.4	0.5	1.9
7	1,104	1,559	7,803	10,466	10.6	14.9	74.6	0.5	0.7	3.6
8	1,302	2,169	12,156	15,627	8.3	13.9	77.8	0.6	1.0	5.6
9	1,767	3,195	46,777	51,740	3.4	6.2	90.4	0.8	1.5	21.5
10	3,226	7,425	85,760	96,411	3.3	7.7	89.0	1.5	3.4	39.5
Total	10,629	18,397	188,156	217,181				4.9	8.5	86.6

Table 3a: Industrial Employment by Income Decile and Plant Size

	Total Industrial Employment by Plant Size Class		
Income Decile	**Small**	**Medium**	**Large**
1	1,780	2,553	17,334
2	3,149	5,438	58,574
3	4,814	12,623	78,124
4	5,623	8,877	56,727
5	7,683	14,712	56,110
6	8,999	16,741	61,737
7	13,034	26,847	132,414
8	16,265	39,178	206,921
9	23,714	62,246	990,049
10	46,777	175,132	1,895,809

5.2 Ambient Quality and Health Damage

Estimating the impact of total emissions on human health (represented here by expected mortality) requires four additional steps.

> First, the World Bank's dispersion model (mentioned in Section 4.1) is used to estimate the impact of industrial emissions on air quality in each municipio. The model incorporates the effects of total emissions, the relative impact of plant size, and the size of the area over which the emissions are dispersed.
>
> The second step is conversion of the concentration increments (by plant size) into changes in the probability of mortality for municipio populations. For this, the particulate 'dose-response' function, developed by Ostro (1994) from a number of prior studies, is deployed. In particular, a 0.1 $\mu g/m^3$ reduction in concentration induces a fall of .067 per 100,000 in the mortality rate.
>
> These estimated concentration increases are then multiplied by municipio population to obtain expected mortality from the emissions of small, medium and large plants.
>
> Finally, the expected numbers of deaths are aggregated across municipios to obtain expected mortality increments by income decile.

The results are portrayed in Table 4.

Do the poor suffer from more pollution in Brazil? In fact, the results strongly suggest the converse. Table 4 shows that 95% of annual expected mortality from industrial air pollution is in the highest two income deciles. Furthermore, the great majority of these deaths (97% in decile 9 and 76% in decile 10) are attributable to emissions from large plants.

Table 4: Expected Deaths from Industrial Particulate Emissions in Brazil

Income Decile[a]	Total Population	Pop. Share (%)	Expected Deaths by Plant Size: Small	Med.	Large	Total	Death Share (%)
1	5,392,439	4.8	1	0	0	1	0.3
2	6,281,428	5.6	0	0	1	1	0.3
3	7,691,836	6.9	1	0	2	3	0.9
4	5,197,602	4.6	0	0	0	0	0.0
5	4,995,732	4.5	1	0	0	1	0.3
6	6,110,057	5.5	1	0	1	2	0.6
7	7,908,071	7.1	3	0	2	5	1.5
8	8,523,451	7.6	3	0	2	5	1.5
9	21,200,000	18.9	4	1	191	196	60.1
10	38,800,000	34.6	23	4	85	112	34.4
Total	112,100,616		37	5	284	326	

[a] Income deciles are not population-weighted. See section 3.2.

These data indicate that industrial air pollution in Brazil is a problem for the relatively affluent, not the poor. Moreover, despite the greater pollution intensity of small enterprises, the mix of sector and plant scale in high-income areas is such that large plants create most of the problem.[7]

[7] It should be emphasized that this study focuses on particulate air pollution from the manufacturing industry alone. Large power plants are a major source of particulate pollution, and including them would obviously increase estimates of deaths

6. Summary and Conclusions

In this paper, we have used new data from Mexico and Brazil to analyze relationships linking economic development, the size distribution of manufacturing plants, and exposure to industrial pollution. Prior work in this field has generally been limited to water pollution and to medium size plants, owing to lack of data. In contrast the present study examines air pollution, and emissions of airborne suspended particulates in particular, and encompasses small plants (with 1-20 employees) as well as medium and large plants (with more than 100 employees).

The data for Mexico indicate that emissions per employee decline with plant size in the aggregate and also within most 3-digit sectors. With the exception of a few sectors (such as basic foods, petroleum products and industrial chemicals) the small plants are the more pollution intensive per employee (and presumably per unit of output).

Some 69 percent of Brazil's municipios report having some manufacturing within their boundaries. Among these industrial municipios, the share of the standard dirty six industries falls continuously with increases in the mean wage of household heads (which is taken as a proxy for level of economic development). These same data also show that the share of the smaller plants (no matter whether measured by the fraction of employment or proportion of plants) is greater among the low wage municipios. Conversely, the large plants are relatively more important in the high wage municipios.

At first glance, these findings seem to imply that the pollution has a 'regressive' bias and that most of the damage is inflicted by small factories. However, the introduction of scaling variables reverses this conclusion: Almost all the pollution damage is in the highest-income areas, and most of it is generated by large plants. The reversal occurs because production volume, plant scale and population density are highly correlated with economic development in Brazil and these effects are not offset by

attributable to large plants. Motor vehicles are another major source of particulate pollution. For an estimate of their contribution to overall mortality in Brazilian municipalities, see Von Amsberg (1997).

reasonable allowances for higher smoke stacks among larger plants.[8]

Do the poor suffer from more pollution? Our results for Brazil strongly suggest the converse. Expected mortality from industrial air pollution is highest in the top two income deciles. Furthermore, the great majority of these projected deaths are attributable to emissions from large plants. This, despite the greater emission intensity of smaller plants and the prevalence of smaller plants in lower income areas.

[8] It is worth noting that our conclusion for air pollution should be doubly valid for industrial water pollution, since there is no ‘stack height’ differential for large and small water polluters. Mixing dynamics are basically the same, so the impact of emissions on water quality is simply a function of volume relative to the local absorptive capacity of the medium. By implication, large plants should account for an even greater share of water pollution in Brazil’s high-income areas.

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