Informal Regulation of Industrial Pollution in Developing Countries: Evidence from Indonesia

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When formal regulation is weak or absent, communities often use other channels to induce pollution abatement by local factories in a process of "informal regulation." The resulting "pollution equilibrium" reflects the relative bargaining power of the community and the plant. This note uses Indonesian data from 1989–90 on plant-level organic water pollution to test the informal regulation hypothesis.

I. Introduction

Under formal regulation, the government acts as an agent for the community in controlling industrial pollution. In the absence of such an institutional agent, a conventional analysis would assume that pollution is costless and essentially unconstrained. However, a growing body of evidence from Asia and Latin America suggests that this is not the case. In developing countries in which formal regulation is weak or absent, many communities have struck bargains for pollution abatement with local factories [1] We term this phenomenon "informal

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[1] To illustrate, we cite three instances: (1) A cement factory south of Jakarta, without admitting liability for the dust it generates, "compensates local people with an ex gratia

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regulation": Acting in their own self-interest, communities make their supply of environmental resources available to polluters at escalating prices (or penalties) as pollution damage rises. Factories find ways to reduce their demand for environmental resources as expected penalties increase. Equilibrium arrangements reflect both demand- and supply-side considerations.

Information and transactions costs are important determinants of such equilibria. Communities must often strike bargains with poor information about plant-level emissions and risks. Without recourse to legal enforcement of existing regulations (if any), they must rely on the leverage provided by social pressure on workers and managers, adverse publicity, the threat (or use) of violence, recourse to civil law, and pressure through politicians, local administrators, or religious leaders. This process is distinct from national or local formal regulation in that it uses other channels to induce compliance with community-determined standards of acceptable performance.[2]

In this note, we test the informal regulation hypothesis using Indonesian data on plant-level organic water pollution. Indonesia provides a good test case. It is large and highly varied, in both environmental and socioeconomic dimensions. Manufacturing has been growing rapidly, industrial pollution is clearly a problem, and, until very recently, most areas have had little or no formal pollution control. Indonesia's data collection system is also efficient and comprehensive, permitting the construction of an appropriate database for this exercise.

II. Industrial Pollution under Informal Regulation

Our model of informal regulation follows convention in defining emissions as the use of "environmental services"—an additional production factor in an augmented KLEM (capital, labor, energy, and materials) framework. The implicit "price" of pollution is the expected penalty or compensation exacted by the affected community.

payment of Rp. 5,000 and a tin of evaporated milk every month" (Cribb 1990, p. 1129). (2) When confronted by community complaints, an Indian paper mill installed pollution abatement equipment. To compensate the community for remaining damage, it also constructed a Hindu temple (Agarwal, Chopra, and Sharma 1982). (3) In Rio de Janeiro, a neighborhood association protest against a polluting tannery led to its relocation to the outskirts of the city (Stotz 1993).

[2] While more subtle pressure seems pervasive, extreme cases are frequently cited in the press. For example, Cribb (1990) tells of "an incident reported from Banjaran near Jakarta in 1980 when local farmers burned a government owned chemical factory that had been polluting their irrigation channels" (p. 1132). Also, the opening of a chemical complex in Korea was stopped by local community action until appropriate pollution control equipment was installed (Clifford 1990).

As factories use up more local environmental quality, the community will impose higher costs.

Survey evidence from Asia suggests that the position of a community's "environmental supply schedule" depends on characteristics such as income, education, level of civic activity, legal or political recourse, media coverage, presence of a nongovernmental organization, the efficiency of existing formal regulation, and the total pollution load faced by the community in relation to the absorptive capacity of the local environment.[3]

Communities with low levels of education and information may give inappropriately low weight to pollution simply because they are not aware of the consequences. Also, communities that consist of the poor, the poorly educated, or members of marginalized minority groups may have little ability to use available regulatory channels.

The "price" of pollution under informal regulation is different from other input prices in two ways. First, it may be plant-specific. Optimizing communities may tolerate polluting factories when they provide a lot of jobs, local contracts, or tax revenues. Communities may engage in Coasian bargaining with firms when reciprocal externalities are recognized. In such cases, both firms and communities may bear some of the cost of reducing exposure to pollution.[4] Communities may also pay particular attention to plants whose location makes them more "visible" and easy to monitor (e.g., large, isolated facilities) or particularly damaging to the local environment (e.g., pulp mills immediately upstream from local fisheries or irrigated rice fields).

Second, the price of pollution is an expectation, not a certainty. Plants learn about expected penalties for damage by observing patterns of community monitoring, activism, and settlements with other local factories: The greater the perceived damage and the community's ability to organize, the higher the compensation exacted by the community.

Faced with an expected price schedule, each plant adjusts pollution to the optimal point along its pollution demand schedule, which is derived from its cost minimization exercise. Potentially significant determinants of the environmental demand schedule include sector,

[3] See Huq and Wheeler (1993) and Hartman, Huq, and Wheeler (1994) for evidence from Thailand, Bangladesh, Indonesia, and India.

[4] A good example is provided by the case of Cubatao, Brazil. In the 1980s, this heavily industrialized valley near São Paulo was afflicted by some of the world's worst air and water pollution. As part of the settlement with local industry, the Cubatao community lowered its exposure level by building low-cost housing and relocating the worst-affected residents away from the most polluted areas. Local industry reciprocated with a significant increase in abatement (see Companhia de Technologia de Saneamento Ambiental 1994).

output, relative input prices, equipment vintage, ownership, and productivity. These factors are discussed briefly below.

Sector.—Sectors such as wood pulping and food processing are both water-intensive and heavy users of organic materials. They have the potential to generate much more organic water pollution per unit of output than sectors such as sawmilling and garment manufacture. Abatement itself requires factor inputs subject to diminishing returns. Cost-minimizing firms in pollution-intensive sectors will therefore have higher equilibrium emissions intensities, ceteris paribus.

Output.—The KLEM framework dictates the use of gross output value as the appropriate measure for this study. Of course, we expect pollution load to grow with output, ceteris paribus. However, most empirical studies of relations between plant size and pollution abatement have suggested that scale economies in abatement are the general rule. Thus we would expect the elasticity of pollution with respect to output to be significantly less than one.

Manufacturing wage.—Applied econometric work on KLEM models has often suggested that (K, E) and (L, M) are complements but that the pairs KE and LM are gross substitutes in production (see Christensen, Jorgenson, and Lau 1973). If this is valid, there will be three relevant effects of a wage increase: (1) energy use and the resultant air pollution from combustion will increase, but organic water pollution should be largely unaffected; (2) materials use and the volume of associated polluting residuals generated will decline; and (3) labor use will decrease in both processing and abatement, and some reduction in abatement activity would also be expected. The impact of a wage increase on organic water pollution is therefore uncertain.

Materials price.—Materials-intensive production tends to be pollution-intensive because the volume of waste residuals is greater. Higher prices for organic material inputs to water-based processing activities should therefore reduce the organic pollution generated.

Capital price.—An increase in the interest rate or the price of equipment will reduce capital and energy use as well as pollution abatement, while increasing the use of labor and materials in processing. The result is ambiguous for air pollution, but reduced abatement and increased materials use should both lead to more organic water pollution.

Energy price.—An increase in energy price will reduce energy use for both processing and pollution abatement. Abatement activity will fall, along with fuel combustion and the associated air emissions. The effects on air pollution are countervailing, but the impact on organic water pollution (if any) is likely to be positive.

Vintage.—Indonesia is still a heavy importer of production equipment from regulated OECD economies, where pollution control has been increasingly embodied in new process technologies. Installation of end-of-pipe abatement equipment during plant construction is cheaper than retrofitting. With rising public concern over pollution in the 1980s, we would expect this cost factor to dictate a stronger response from new factories. "Green consciousness" in some industrial societies may also drive their internationally oriented construction contractors to pressure their clients toward greater abatement. For all these reasons, we would expect newer plants to be cleaner.

Efficiency.—More productive firms should be better managed and more capable of responding to incentives for pollution control. They should also generate less waste per unit of output. We would therefore expect such firms to be cleaner.

Ownership.—Most multinational firms in Indonesia are headquartered in richer, more regulated economies in which they have relatively low-cost access to clean technologies developed for the firms' OECD plants. Multinationals may also be more sensitive about their public image. We would therefore expect foreign-owned firms to be cleaner than their local counterparts.[5] Publicly owned plants, on the other hand, are quite likely to be older, less efficient, and therefore more pollution-intensive than their private counterparts. After these factors are accounted for, however, the residual effect of public ownership is not clear. We might expect lower pollution intensity for public plants operating under soft budget constraints because they do not confront the full cost of abatement. However, bureaucratic control may also shield state-owned facilities from local pressure.

A. *The Quantity and Implicit Price of Pollution in Equilibrium*

The following equations summarize environmental demand/supply relations under informal regulation, using the concept of equilibrium pollution in an implicit "market for environmental services." Expected signs of partial derivatives are noted with the variable definitions (a question mark denotes uncertainty).

Demand.—The demand for environmental services from the firm is given by[6]

$$P_{ij} = f(W_{pij}, s_i, Q_i, W_{lj}, W_{ej}, W_{mj}, v_i, f_i, m_i, g_i), \qquad (1)$$

[5] There is substantial anecdotal evidence to support this proposition (see, e.g., Birdsall and Wheeler 1993). However, a study of abatement by pulping mills in four Southeast Asian countries by Hartman et al. (1994) finds no effect of ownership after efficiency is accounted for.

[6] Capital price is not included because interest rates do not vary across Indonesia and we have no evidence on variation in equipment prices.

where P_{ij} is total biological oxygen demand emissions from plant i in community j; $-W_{pij}$ is the expected pollution price for plant i; $?s_i$ is the sector of plant i; $+Q_i$ is the total output of plant i; $?W_{lj}$ is the manufacturing wage in community j; $+W_{ej}$ is the energy price index in community j; $-W_{mj}$ is the material input price index in community j; $+v_i$ is the age of plant i; $-f_i$ is the factor productivity of plant i; $-m_i$ is the foreign ownership status of plant i (percentage share of equity); and $?g_i$ is the public ownership status of plant i (percentage share of equity).

Supply.—The environmental supply schedule faced by the plant reflects the expected price it will pay for pollution at each level. This is modeled as

$$W_{pij} = f(P_{ij}, y_j, e_j, n_{ij}, a_j, t_j), \tag{2}$$

where $+P_{ij}$ is the total emissions from plant i in community j; $+y_j$ is per capita income in community j; $+e_j$ is the postprimary schooling rate in community j; $?n_{ij}$ is the share of plant i in total manufacturing employment in community j (it measures a plant's economic attractiveness to the community [$-$] as well as its visibility [$+$]); $?a_j$ is urbanization proxied by population density (it measures plant visibility [$-$] as well as the size of the affected population [$+$]); and $+t_j$ is the total pollution load faced by community j.

We can solve for the firm's equilibrium pollution as

$$P_{ij}^{*} = f(W_{lj}, W_{ej}, W_{mj}, Q_i, s_i, v_i, f_i, m_i, g_i, n_{ij}, y_j, e_j, a_j, t_j). \tag{3}$$

B. *The Roles of Sector and Location*

Equations (1) and (3) treat the production sector as an exogenous variable. However, sectors differ greatly in average pollution intensity.[7] Ceteris paribus, plants in pollution-intensive sectors should avoid areas with high expected pollution prices. Within sectors, of course, abatement should be more intensive in such areas. Since both factors are potentially important, this exercise estimates regression models both with and without sector controls. The latter permit an assessment of the full impact of right-hand variables, operating through both sectoral location and abatement decisions.

C. *Possible Endogeneity of Income and Education*

Our model employs community income and education levels as exogenous variables. We recognize that in an urban area in which all

[7] For a detailed analysis of sectoral pollution intensities, see Hettige et al. (1994).

agents are mobile, this assumption could easily be wrong. Location of a polluting factory in a particular district could trigger locational sorting by income class, with wealthier families moving away to escape the pollution and poorer families moving in as rents fall. In our case, however, the argument for endogeneity is far less compelling. The units of analysis are *kabupaten*, subprovincial districts roughly analogous to U.S. counties. They are drawn from a broad spectrum of urban and rural areas across three different islands: Java, Sumatra, and Kalimantan. Indonesia exhibits great spatial variation in community cultures; the relative social and economic status of *kabupaten* has changed little since 1975. During that period, however, almost all of Indonesia's manufacturing has come into existence. Therefore, *in our case, industrial location dynamics clearly dominate residential location dynamics.* If there is any bias in our estimates, we are confident that it is small.

D. *Econometric Specification*

Our basic pollution demand equation, $P = f(W_p, W_l, W_e, W_m, Q)$, could be derived along with other input demand equations from a generalized cost function under the assumption of cost minimization. However, estimation of a multiequation input demand system seems too cumbersome to be worthwhile at this point for several reasons. First, W_p is endogenous and has many determinants. There are also many plant-specific demand-shift variables in the model. Our sample is not large, and we know that measurement errors for the left-hand variable, while probably normally distributed, are also quite large in some cases. We therefore confine ourselves to estimation of log-log regressions, with dummies for categorical variables.

Heteroscedasticity across observations, often a problem with cross-section analyses, was not a significant problem in our data. We have, however, reported White heteroscedasticity-consistent results. Although there is fairly significant correlation between different groups of variables in our data set, multicollinearity does not appear to have been a problem for estimation.

III. The Data

This study combines Indonesian manufacturing and socioeconomic census data, provided by Indonesia's Central Statistics Bureau (BPS), with observations on plant-level water pollution. The latter were gathered by Indonesia's National Pollution Control Agency (BAPEDAL) as part of its Clean Rivers (PROKASIH) program in Java, Sumatra, and Kalimantan. All observations pertain to the period 1989–90.

TABLE 1

SUMMARY STATISTICS: SAMPLE FACTORIES AND *KABUPATEN*

Variable	Mean	Standard Deviation	Minimum	Maximum
Factory variables:				
BOD load (kg/day)	448.38	1,695.65	.02	16,655
Output (000,000 rupiah/ year)	33,106.9	139,140.1	85.8	2,130,000.0
Wage (000 rupiah/year)	977.53	349.70	294.73	2,086.58
Fuel price (000 rupiah/ million Btu)	17.59	1.36	14.11	22.73
Value added per worker (000 rupiah/year)	23,237	40,786	155.32	274,445
Age (years)	13.35	13.29	1	90
Foreign ownership (%)	13.74	27.69	0	100
State ownership (%)	6.32	23.46	0	100
Local employment share (%)	.03	.08	.0002	.91
Kabupaten variables:				
Income per capita (000 rupiah/year)	501.63	146.97	256.45	837.28
Percentage education greater than primary (%)	29.00	12.53	6.85	48.47
Population density (pop/ km^2)	3,948	5,242	3.43	53,876

Summary statistics on the variables used in this analysis are provided in table 1.

A. *The Measure of Water Pollution*

We focus on biological oxygen demand (BOD),[8] the most commonly regulated water pollutant in both industrial and developing countries. It measures the oxygen used during the breakdown of organic pollutants by naturally occurring microorganisms. This process removes dissolved oxygen from the water and can seriously damage some fish species as well as accelerate the growth of undesirable algae. The most common measure of BOD is the amount (kilograms) of oxygen used (per unit of effluent) over 5 days to completely oxidize the organic pollutants in the effluent. The PROKASIH 5-day BOD measure (kilograms per day) for each plant is calculated using data on total effluent volume generated per day.

Indonesia's first nationwide program for industrial pollution con-

[8] An equivalent term, biochemical oxygen demand, is now commonly used in the OECD. We follow current Indonesian usage in this paper.

trol was PROKASIH. We employ a cross section of benchmark BOD measures, taken at the beginning of PROKASIH, which reflect the environmental performance of Indonesian factories before the institution of nationwide formal regulation. Large-sample tests of data validity by an outside consultant and the Environment Ministry show that they provide unbiased, robust estimates (Afsah 1994). We expect sampling errors to generate relatively high "unexplainable" variance in the data set, but tests of significance should not otherwise be affected.

B. *Plant Characteristics*

Our data on plant characteristics are drawn from the Annual Census of Manufactures administered by BPS. This detailed census has been administered by BPS since 1975 and has been subjected to frequent and rigorous checks. Standard census data have been used for our measures of total output value, age, and local employment share for the PROKASIH plants. The latter variable is constructed by calculating total *kabupaten* manufacturing employment from the 1989 census and dividing plant-level employment by this total. Because we do not have sufficient data for an estimate of total factor productivity, we have used reported value added per production employee as our proxy. Foreign ownership is measured by census data on the proportion of firm equity held by foreigners. The total proportion of equity held by the regional and central governments measures public ownership. We have included dummy controls for sectors that both are well represented in the data set and potentially emit large quantities of organic waste: food products (International Standard Industrial Classification 3121), textile spinning and weaving (3211), tanneries and leather finishing (3231), sawmills and wood mills (3311), and pulp, paper, and paperboard (3411). Recent empirical evidence suggests that food products and pulp/paper should have the highest BOD intensities in this set, ceteris paribus, whereas woodworking mills should have the lowest (see Hettige et al. 1994).

C. *Input Prices*

We have used the 1989 manufacturing census to compute for each *kabupaten* a price index for energy, incorporating the prices (per million British thermal units [Btu]) of electricity, gasoline, high-speed diesel oil, diesel, kerosene, natural gas, coke, and coal. The weights are national energy expenditure shares for each fuel. Our estimate of local labor price is the mean plant-level wage for production workers across all census plants in the *kabupaten*. We have no direct measure of relative materials prices by sector, but we use a Java location dummy as a proxy for transport cost considerations for heavy materials in pollution-intensive sectors. Factories on Java now import much of their heavy materials from other islands, thus facing relatively higher transport-related costs.

D. *Community Characteristics*

Our estimates for *kabupaten* per capita expenditure, postprimary education, and population density are drawn from the SUSENAS surveys conducted by BPS in 1988 and 1990. Per capita household expenditure was judged to be the most reliable available measure of living standards and was used as a proxy for per capita income.

IV. Results

Table 2 presents the results for pollution regressions estimated with and without sector controls. They are strongly consistent with our basic thesis: Without any formal regulation, equilibrium emissions vary strongly across firms and regions in response to differences in scale, regional input prices, firm characteristics, and the degree of informal regulation by local communities. Parameter signs and standard error estimates are mostly stable across models 1 and 2. Our interpretation of the results is based on model 1 since it incorporates both locational and abatement responses.

As expected, the estimated output elasticity of water pollution (0.65) is significantly less than one: Pollution intensity (i.e., pollution per unit of output) declines with scale, decreasing 0.35 percent for each 1 percent increase in output. Thus, if we normalize by output, larger plants are cleaner than smaller ones. Our results on inputs suggest weak complementarity for labor and energy but, as expected, strong complementarity for materials. However, the Java location dummy is admittedly a crude proxy for relative materials prices. There may also be some reflection of power here (Java remains the political heartland of Indonesia), although we have included separate controls for community income and education.

Firm and plant characteristics appear to have a strong impact on pollution intensity. As expected, plants in the food and paper sectors have the highest pollution intensity, ceteris paribus. More productive plants are cleaner, as hypothesized: Pollution intensity changes by about 0.3 percent in response to each 1 percent change in value added per worker. Older plants are dirtier, but the latter effect is not as strong as we would have supposed a priori.

After we control for scale, age, and efficiency, foreign participation

TABLE 2

Regression Results

Dependent Variable: Log BOD Load (N = 243)

Variable	Model 1 (Adjusted R^2 = .3146) Coefficient Estimate	t-Statistic	Model 2 (Adjusted R^2 = .3805) Coefficient Estimate	t-Statistic
Intercept	31.580 (6.76)	4.67***	17.479 (7.32)	2.39***
Demand variables:				
Log(output)	.647 (.19)	3.34***	.712 (.19)	3.78***
Log(wage)	−.740 (.62)	−1.20	−.316 (.61)	−.52
Log(fuel price)	−2.257 (2.42)	−.93	−1.267 (2.44)	−.52
D(Java)	−1.231 (.55)	−2.23**	−1.530 (.51)	−2.98***
Firm variables:				
Log(value added per worker)	−.325 (.18)	−1.81*	−.312 (.17)	−1.79*
Log(age)	.273 (.17)	1.64	.179 (.17)	1.07
Foreign ownership	−.002 (.01)	−.27	.0004 (.01)	.06
State ownership	.017 (.01)	2.64***	.021 (.01)	2.91***
Informal regulation:				
Log(local employment share)	−.352 (.18)	−1.94*	−.313 (.17)	−1.84*
Log(income per capita)	−4.021 (.91)	−4.41***	−2.811 (.93)	−3.02***
Log(percentage education greater than primary)	−1.072 (.57)	−1.87*	−.668 (.57)	−1.17
Log(population density)	.344 (.17)	2.04**	.128 (.21)	.62
D(textiles)			1.247 (.37)	3.41***
D(leather tanning)			1.961 (.63)	3.12***
D(food)			2.480 (.55)	4.52***
D(pulp, paper)			2.265 (.57)	3.98***
D(wood products)			−.930 (.92)	−1.02

Note.—White heteroscedasticity-consistent standard errors are in parentheses.
* H_0: $\beta = 0$ rejected with 90 percent confidence (two-tail).
** H_0: $\beta = 0$ rejected with 95 percent confidence (two-tail).
*** H_0: $\beta = 0$ rejected with 99 percent confidence (two-tail).

does not have a significant effect on pollution intensity. In fact, foreign participation remains insignificant even when we exclude these variables from the regressions. Our results therefore suggest that the anecdotal stereotype of clean foreign firms is misleading, at least for Indonesia. Public ownership, on the other hand, is strongly associated with "dirty" production. Thus our posited "shielding" effect seems to outweigh any leverage from soft budgets.

Our results for community income and education are strongly consistent with the informal regulation hypothesis. The estimated income elasticity of pollution reduction is highly significant and extremely large: Pollution intensity declines 4 percent with each 1 percent increase in community income. Given a threefold range in sample community incomes, this implies a major impact.[9] Although income and education are highly correlated (r = .67), education has a separate and significant impact in model 1: Pollution intensity declines 1 percent with each 1 percent increase in community share of residents with greater than primary education. Given the sevenfold range of variation in the sample, this suggests a major, separate impact for community education.

The results for plants' local employment share and population density reflect the net impact of visibility and other factors. The visibility effect seems clearly dominant: Plants with higher local employment shares have lower pollution intensities, ceteris paribus; plants in less densely populated areas are less pollution-intensive.[10]

V. Summary and Implications

Econometric work on determinants of pollution intensity at the plant level is scarce even in the OECD economies. As far as we know, this is the first such study for a developing country. Our results suggest that, even in the absence of any formal regulation, the intensity of factory-level water pollution in Indonesia has been highly responsive to many variables that can be affected by nonenvironmental policies.

To analyze the magnitude of these effects, we simulated the comparative impacts of key firm and community characteristics using sample first and third quartiles. Our results suggest that *an old, unproductive plant* (seventy-fifth percentile age, twenty-fifth percentile value added per worker) *is about 2.4 times more water pollution–intensive* than a young, productive facility (twenty-fifth percentile age, seventy-fifth percentile value added per worker). *Public enterprises are about 5.4 times more water pollution–intensive* than plants owned by private firms. *Plants in poor, less educated areas* (twenty-fifth percentile income and

[9] Wage and the per capita income proxy are highly correlated (r = .61), but our results strongly suggest that pollution-labor complementarity does not confound the informal regulation hypothesis. With income included, the estimated wage effect is weak but the income effect is extremely strong. When income is excluded, the wage elasticity increases, but so does the estimated effect of community education. When wage is dropped, the income effect becomes even stronger, but there is no significant impact on the education elasticity.

[10] As noted in Sec. II, a more complete test of the informal regulation hypothesis would include a measure of local ambient water quality or, as a proxy, an index of water pollution load relative to local absorptive capacity. The relevant variables were not available for this study. We tested a very crude version, using total *kabupaten* population as a proxy for total organic waste generated. This did not improve model fit, nor was the coefficient on population significant.

education) *are about 15.4 times more water pollution–intensive* than plants in relatively affluent, well-educated (seventy-fifth percentile) areas.

Given these results, recent policy trends in Indonesia hold considerable promise for cleaner industrial production. Few state-owned factories will be built in the future; also, greater competition has been increasing plant-level efficiency in the private sector. Postprimary education and per capita income are advancing steadily throughout Indonesia. If cross-section results can be extrapolated to time series, these trends should be associated with large declines in the pollution intensity of Indonesian manufacturing, no matter what happens to formal regulatory policy. Furthermore, the predicted effect does not depend on any increased presence of foreign, putatively "green," firms in the country.

While these trends are promising, they should not obscure the fact that production is much dirtier in poor, uneducated communities. Income-based preferences undoubtedly play a part in this, but the significance of education and the sheer size of the disparity suggest important roles for information and political power as well. Our results therefore suggest that "environmental injustice" may be an important issue in Indonesia.

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