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Formal and Informal Regulation of Industrial Pollution: Comparative Evidence from Indonesia and the United States

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Economic theory and recent empirical work suggest that when formal regulation of pollution is absent or less than 100 percent effective, affected communities are often able to negotiate abatement from plants in their vicinity through "informal regulation." Using a model of equilibrium pollution, this article confirms the existence of significant informal regulation for unregulated pollutants in both Indonesia and the United States as well as for regulated pollutants in the United States. Combining plant-level data with community data in both countries, regressions reveal that even after controlling for traditional economic variables such as output levels and input prices as well as for plant characteristics such as industrial sector and age, the per capita income of affected communities significantly affects pollution intensities. Higher-income communities win significantly lower emissions in both *countries and for* both *unregulated and regulated pollutants in the United States, presumably because income affects* both *preferences for environmental quality and the ability to bring pressure on polluting factories.*

This article starts from the premise that governments, using the various instruments at their disposal, act as agents of the public in regulating pollution. However, when formal regulatory mechanisms are absent or ineffective, communities seek other means of translating their preferences into reality. Recent empirical work indicates the widespread existence of such "informal" regulation through which communities are often able to negotiate with or informally pressure polluting plants in their vicinity to clean up.

Formal regulatory mechanisms include both command and control instruments (effluent concentration standards, technology standards) and market-based instruments (emissions charges, abatement credits, tradable permits). Informal regulation also takes many forms, including demands for compensation by

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community groups, social ostracism of the firm's employees, the threat of physical violence, boycotts of the firm's product, and efforts to monitor and publicize the firm's emissions (for examples, see Pargal and Wheeler 1996). Implicitly, such actions force firms to recognize the community's property rights in the local environment. They frequently work because firms do not operate in a social vacuum. When informal regulation is effective, local factories face a positive expected penalty for polluting.

Informal regulation need not be limited to cases where formal regulation is absent. If formal regulatory standards and institutions exist, the most effective informal regulatory tactic may be to report violations of legal standards. This is easier if information on standards is widespread, monitoring is relatively costless, and violators are easy to identify. A second "formal" channel for informal regulation is to pressure regulators to tighten their monitoring and enforcement. Profit-maximizing firms reduce pollution to the point where the marginal cost of abatement equals the expected marginal penalty for noncompliance. Because regulators have limited resources, polluters know that many regulatory violations will go undetected or be lightly penalized. For recent evidence from North America, see Deily and Gray (1991); Dion, Lanoie, and Laplante (1996); Magat and Viscusi (1990); and Russell (1990). Similar evidence for Asia can be found in Dasgupta, Huq, and Wheeler (1997); Hartman, Huq, and Wheeler (1997); O'Connor (1994); and Wang and Wheeler (1996). In this context, public pressure on regulators can be an important countervailing force.

Our thesis is that such informal regulation will be likely wherever formal regulation leaves a gap between actual and locally preferred environmental quality. If our hypothesis is correct, we would expect widespread informal regulation in developing countries where formal regulation of pollution is absent or ineffective. However, informal regulation may also be common in industrial countries that have nationally uniform regulatory standards. In this case, formal and informal pressure on plants to abate may vary significantly with local preferences and organizational capabilities. We would expect informal regulation to be strongest in richer communities because they have stronger preferences for environmental quality and more knowledge about the risks of pollution. In addition, such communities are more capable of exerting political, social, and economic pressure.

In this article, we use plant and community data from the United States and Indonesia to test for the effect of informal regulation in a general model of "equilibrium pollution." This model, first developed in Pargal and Wheeler (1996), posits the existence of community-level emissions equilibria at points determined by local environmental demand and supply schedules. Industry's environmental demand (or pollution) schedule reflects the marginal cost of abatement. The position and slope of the schedule are pollutant-specific and depend on three sets of variables: the expected cost of pollution, determined by formal and informal regulation, standard economic factors such as abatement scale economies and relative input prices, and a variety of plant and firm characteristics such as vintage of the equipment, efficiency, and ownership. The positions and slopes of environmental supply schedules for specific pollutants also reflect three sets of factors: community perception of damage, valuation of that damage, and the ability to impose costs on polluting facilities via formal or informal regulatory channels.

The intersection of environmental demand and supply schedules is, of course, a familiar conceptual device in environmental economics textbooks (see, for example, Tietenberg 1992). However, the conventional treatment identifies "optimal" pollution at the intersection of marginal cost and marginal damage schedules, implicitly assuming transactions costs to be zero for the regulator. By contrast, we assume that formal regulation and informal regulation are affected by the costs of information, organization, and enforcement. Thus local equilibrium emissions may differ significantly from "optimal" emissions, which are derived solely from marginal cost and damage functions. Of course, they may also differ significantly from the emissions that are mandated by formal regulatory standards.

The United States and Indonesia provide good test cases, because they occupy nearly opposite ends of the regulatory and socioeconomic spectra. In the United States, many air and water pollutants have been regulated at the national level for more than two decades. The U.S. Environmental Protection Agency (EPA) has a large staff, good technical facilities, and a record of tough enforcement. Indonesia, by contrast, had no regulatory standards before 1992, and at present, enforcement of these standards is mostly limited to a few water pollutants. The monitoring and enforcement capabilities of Indonesia's National Pollution Control Agency (BAPEDAL) are extremely limited, technical staff are almost nonexistent, and very few actions have been taken against noncompliant facilities.

The same extremes apply to socioeconomic data. The United States is one of the world's richest, best-educated societies, while Indonesia has only begun to reach lower-middle-income status after three decades of rapid growth and industrialization. Both societies are, however, extremely diverse both geographically and socially. In addition, both have large differences between incomes in different geographical communities. Thus it is plausible to assume that informal regulation may play an important role in both societies. We would certainly expect equilibrium emissions per unit of output to be higher in Indonesia. However, we would also expect substantial intercommunity differentials in both countries and, possibly, an overlap in the tails of the distributions.

In this article, we compare econometric analyses of plant-level emissions across communities in the two countries. Our geographic units are counties in the United States and *kabupaten* (subprovincial units) in Indonesia. For the United States, we include regressions for emissions of two regulated air pollutants (total suspended particulates, TSP, and sulfur dioxide, SO_2); two regulated water pollutants (biological oxygen demand, BOD, and total suspended solids, TSS); and total emissions of toxic compounds, many of which are not formally regulated at present. For Indonesia, we reproduce results for BOD that were previously reported in Pargal and Wheeler (1996). BOD is the only pollutant for which large-sample data are currently available in Indonesia.

Section I briefly describes the institutional setting in the United States and Indonesia. Section II describes our model of equilibrium emissions under formal and informal regulation. Section III specifies the regression equation and describes our data. Section IV reports results and implications, and section V presents a summary and conclusions.

I. INSTITUTIONAL BACKGROUND

Socioeconomic conditions and regulatory history are quite different in Indonesia and the United States. Yet both countries have conditions that give rise to large pollution differentials among communities.

Regulation in the United States

Criteria air and water pollutants have long been regulated by command-and-control methods in the United States. Air pollution control has historically been based on uniform emissions standards, starting with creation of the EPA and passage of the Clean Air Act Amendments of 1970 (Tietenberg 1992). EPA regulatory acts have included ambient air quality standards, the designation of areas as nonattainment regions, the application of guidelines for "prevention of significant deterioration," and mandated installation of specific control technologies at the plant level. Substantial noncompliance penalties exist, and there is little flexibility in the imposition of environmental regulations under the Clean Air Act.

The control of conventional water pollutants has also been based on national effluent standards at the industry level, which are derived from technological specifications. There is less emphasis on uniform ambient standards than there is for air quality regulation, possibly reflecting the different impacts of pollution in the two media. At present, responsibility for regulating the manufacture and use of toxic substances is shared by several agencies including the EPA, the Food and Drug Administration (FDA), and the Occupational Safety and Health Administration (OSHA). The EPA regulates the handling, shipping, and disposal of hazardous or toxic pollutants in the United States. Legal recourse for damage under common law is a valuable complement to these regulations. Some toxics are clearly very dangerous, but many others have uncertain effects on human health and ecosystem functioning. At present, the EPA does not have safety or "emission/effluent" standards for the majority of toxic pollutants. As an aid to community awareness of exposure risk, however, it has since 1987 published an annual Toxic Release Inventory (TRI). The TRI, which was legislated in 1986 by the Emergency Planning and Community Right-to-Know Act, is based on mandated disclosure of toxic releases and transfers by U.S. industrial facilities. Substantial penalties can be imposed for failure to comply with reporting requirements, but the TRI is basically a public information tool. Local governments or community groups must assess the performance of listed firms in their vicinity and act on this information as they deem fit—by negotiation, public appeals, citizen suits, and so forth.

To summarize, the United States has administered a system of formal, command-and-control regulation of criteria air and water pollutants for more than two decades. Limited use of tradable pollution permits has begun, notably in the case of the national trading program for SO_2 emissions permits under the revised Clean Air Act. For the most part, however, the U.S. system continues to rely on command-and-control regulation rather than on pollution taxes or tradable pollution permits. Analysis of plant-level emissions of these pollutants should therefore provide a good test of the degree to which local environmental demand-supply considerations complement the enforcement of national uniform standards in pollution control. By contrast, the lack of formal regulation for toxic emissions provides a good case for analyzing the influence of informal regulation unaided by national standards.

Regulation in Indonesia

Indonesia began formal regulation in 1992, with establishment of maximum allowable volumes and concentrations (in kilograms per ton of output) for emissions of BOD and other water pollutants from 14 broadly defined industry sectors (such as textiles and wood pulping). Although self-reported BOD emissions are now mandated by law, reporting has been extremely sparse. Expansion of self-reporting has recently begun under the PROPER program for rating and disclosing the environmental performance of industrial facilities (see Afsah and Wheeler 1996). Until 1995 the only program of monitoring and pressuring for compliance was a voluntary arrangement instituted in 1989. This PROKASIH, or Clean Rivers, program covers about 5 percent of Indonesian manufacturing facilities in 11 river basins on the islands of Java, Sumatra, and Kalimantan. Although it has succeeded in eliciting significant pollution reductions from some of Indonesia's largest polluters, PROKASIH represents only the first stage of regulation. See Afsah, Laplante, and Makarim (1996) for a detailed analysis of the PROKASIH program. Formal regulation of air and toxic pollution has only recently been introduced. Thus Indonesia provides a good test of the significance of informal regulation in a developing country where formal regulation is still in its infancy.

II. A Model of Equilibrium Emissions under Informal Regulation

This article presents a summary version of our model of informal regulation as developed in Pargal and Wheeler (1996). The model follows convention in defining emissions as the use of "environmental services"—an additional factor of production in an augmented KLEM (capital, labor, energy, materials) framework. The implicit "price" of pollution is the expected penalty or compensation exacted by the affected community. It is different from other input prices in that it may be plant specific. Optimizing communities may tolerate polluting factories when they provide significant employment, local contracts, or tax revenues. Conversely, they may pay particular attention to plants whose location makes them easy to monitor, such as large, isolated facilities, or whose emissions are particularly damaging to the local environment, such as pulp mills immediately upstream from local fisheries or irrigated fields.

Informal Regulation and Coasian Economics

There is clearly a relationship between the concept of informal regulation and the Coasian view of environmental economics. Both consider the process by which externalities are internalized in the absence of regulatory agents, and both acknowledge that an externality can be created by the action of either a polluter or pollutee. An externality can be generated when a household or firm moves into proximity with a polluter. In the law, this is called "coming to the nuisance" (Cooter and Ulen 1988: 181). For further discussion, see Calabresi (1970), Coase (1960), Coelho (1975), Demsetz (1967 and 1988), Diamond (1974), Hartman (1982), and McKean (1970). However, the traditional Coasian solution depends on a well-defined legal and institutional environment. Efficient outcomes require accurate information about pollution problems, clear delineation of environmental property rights, and courts that are able and willing to enforce legal agreements.

We do not question the relevance of these conditions in many cases, but our view of informal regulation extends the Coasian view in two ways. First, community pressure clearly affects polluters' behavior even where there is little accurate information, no explicit agreement about environmental property rights, and no court system able to adjudicate settlements. Second, our research and other studies suggest that the conceptual distinction between Coasian arrangements and traditional regulation is often blurred in practice. Regulators must confront strategic behavior by polluters and frequently renegotiate compliance schedules and penalties. And community pressure may significantly affect these interactions, creating de facto informal regulation even in countries where information is plentiful, formal regulations are clearly defined, and the legal system functions effectively.

Environmental Supply

Informal regulation reflects local factories' implicit acceptance of the community's property rights in the environment. Communities use their leverage to impose penalties (costs) on firms whose emissions are judged to be unacceptable. As factories use up more local environmental quality, affected communities impose higher costs. From the viewpoint of industry, the result of informal regulation is an environmental supply schedule that shifts inward as average community income increases. Field survey evidence from Southeast Asia suggests that this schedule depends on several factors: the level of community organization, information, legal or political recourse, media coverage, the presence of nongovernmental organizations, the efficiency of existing formal regulation, and the opportunity cost of time. Many of these factors are correlated with community income levels. For more detailed discussion, see Huq and Wheeler (1993); Hartman, Huq, and Wheeler (1997); and Hettige and others (1996). This supply schedule is expected to be flat with respect to income only if formal regulation is completely successful in equalizing emissions across locations.

Environmental Demand

Faced with an environmental supply schedule, each plant adjusts pollution to the optimal point along its pollution demand schedule, derived from its cost minimization exercise. As noted in Pargal and Wheeler (1996), potentially significant determinants of the environmental demand schedule include industrial sector, output levels, relative input prices, vintage and efficiency of technology, and, in the case of Indonesia, ownership. The latter variable is not a significant source of variation in the United States given the preponderance of domestic, private firms in the economy. However, in Indonesia we might expect the effect on pollution intensity to be positive for state-owned firms and negative for multinationals.

Pollution seems likely to be complementary to material inputs, but its cross-price relationships with labor, capital, and energy are not clearly signed. For this study, we construct local labor and energy price indexes for both the United States and Indonesia and a proxy for materials price variation across regions in Indonesia. The absence of capital price information is not a major concern, because both of our samples are cross-sectional and we would not anticipate much within-country variation in the price of this factor.

Well-managed plants should generate fewer waste residuals per unit of output and respond more readily to incentives for pollution control. To the extent that profitability reflects efficiency, well-run plants should also have more discretionary funds with which to satisfy the demands for cleanup. Profitability, however, is a double-edged sword in this context, because firms that have avoided pollution abatement should have lower operating costs, other things being equal. Thus although efficient management should have an unambiguously negative effect on a plant's pollution intensity, proxies based on measures of profitability might have a "perversely" positive effect in regressions if the cost-saving component is dominant.

Equilibrium Pollution

Following the supply/demand derivation in Pargal and Wheeler (1996), we solve for the following reduced-form equation, which characterizes a plant's equilibrium pollution, P_{ij}:

$$P_{ij} = f(W_{lj}, W_{ej}, W_{mj}, Q_i, s_i, v_i, f_i, m_i, g_i, n_i, a_j, y_j). \tag{1}$$

Right-hand variables for the regression equation are defined as follows, with expected signs of estimated parameters indicated in parentheses. See Pargal and Wheeler (1996) for a detailed discussion. There are five standard demand variables: W_{lj} is the manufacturing wage in county j (uncertain), W_{ej} is the energy price index in county j (uncertain), W_{mj} is the material input price index in county j (negative), Q_i is the total output of plant i (positive, with elasticity less than 1), and s_i is the sector of plant i (uncertain). There are four firm-specific variables: v_i is the age of plant i (positive), f_i is the factor productivity of plant i (uncertain), m_i is the multinational status of plant i (1 if multinational; negative), and g_i is the public/private status of plant i (1 if public; uncertain). There are three informal regulation variables: n_i is the share of plant i in county j's manufacturing employment (uncertain), a_j is the population density in county j (uncertain), and y_j is the per capita income in county j (negative).

The Roles of Industrial Sector and Location

As previously mentioned, broadly defined industry sectors differ greatly in average pollution intensity of production (see Hettige and others 1994). However, even in sectors with high pollution potential, emissions can often be substantially reduced by modifying the process or installing end-of-pipe abatement equipment. Investors simultaneously choose products, processes, and abatement levels, taking relative prices at different locations into account. In general, we would expect emissions per unit of output to be relatively elastic with respect to the local "price of pollution."

Possible Endogeneity of Income

Our model employs community mean income as an exogenous variable, but we recognize the risk of endogeneity. Within an urban region, where residential mobility is comparable to factory mobility, an increase in pollution-intensive manufacturing in some areas may induce a decline in average income as richer people move away and lower property prices attract poorer people. This may well have been a significant factor in some U.S. metropolitan areas. If so, the result would be an upward-biased estimate of the impact of informal regulation (proxied by community income) on plants' abatement decisions. However, our results (section IV) suggest that simultaneity bias is not a significant problem for our U.S. regressions.

In the Indonesian case endogeneity is far less likely. The units of analysis are *kabupaten* drawn from a broad spectrum of urban and rural areas in Java, Sumatra, and Kalimantan whose relative social and economic status has changed little since 1975. However, most of Indonesia's manufacturing has developed during the past two decades. Therefore industrial location clearly dominates residential migration in the Indonesian case. If there is any bias in our estimates, we are confident that it is small.

Econometric Specification

We have no strong prior views on appropriate specification of the estimating equation for equilibrium pollution. Because our theory of informal regulation has not been extensively tested, we start with a relatively simple and tractable empirical exercise. The pollution price variable is endogenous, with many determinants, and there are many plant-specific demand-shift variables in the model. We therefore limit ourselves to estimating log-log regressions, using dummies for categorical variables.

Heteroscedasticity, often a problem with cross-sectional analyses, is not a significant problem in our U.S. data. For Indonesia, we have reported White heteroscedasticity-consistent results. Although the correlation between different groups of variables is fairly significant in our Indonesia data set, multicollinearity is apparently not a problem for estimation.

III. THE DATA

U.S. data used for this study were obtained by merging establishment-level manufacturing data from the U.S. Census Bureau's Longitudinal Research Database (LRD), county income and population data from the U.S. Census Bureau's "U.S.A. Counties on CD ROM" (COSTAT), and EPA data from various sources: the TRI for toxics, the Aerometric Information Retrieval System (AIRS) for air emissions, and the National Pollutant Discharge Elimination System (NPDES) for water pollutant discharges.

Indonesian manufacturing and socioeconomic census data were combined with observations on plant-level water pollution measured as part of the Environment Ministry's PROKASIH program during the period 1989–90. Our plant-level emissions data were provided by BAPEDAL. Data on plant characteristics and socioeconomic characteristics of communities were provided by BPS (Indonesia's Central Statistics Bureau) and are described in Pargal and Wheeler (1996).

U.S. Variables

For the U.S. case the dependent variables in our analysis include two air pollutants (SO_2 and TSP), two water pollutants (BOD and TSS), and the total quantity of toxic releases. We measure the volume of emissions in kilograms per day for both BOD and TSS; and toxics, SO_2, and TSP in pounds per year.

Our data on U.S. plant characteristics, drawn from the LRD and COSTAT, include measures of output value, plant age, and county-level employment share. As in the Indonesian case, we use value added per employee as a proxy for productive efficiency. We also include dummy variables for all nine two-digit U.S. Standard Industrial Classification (SIC) manufacturing sectors.

Data for our U.S. energy price index were obtained for each state for 1987 from the *State Energy Price and Expenditure Report of 1991*, published by the Energy Information Administration (1991). This is a composite index for the industrial sector created from coal, natural gas, petroleum, and electricity prices, in dollars per million British thermal units. The local manufacturing wage in the United States is computed from the LRD as the mean plant wage for each county. We lack direct measures of relative materials prices by sector and exclude them from the U.S. regressions.

Data Description

The U.S. data set used for toxics is the largest, with 12,005 observations common to the LRD and TRI. The characteristics of more than 2,000 matching counties vary significantly, with first and third quartiles of population density and per capita income ranging from 109 to 1,403 people per square mile and $10,000 to $13,075, respectively. Plant characteristics for the toxics sample are represented by a mean age of 25 years, mean wage of $22,000 a year, and a mean local employment share of 5.6 percent.

The air pollution data for the U.S. include 1987 emissions information from 878 plants in the AIRS data base that could be matched with the LRD. The matching community characteristics are less widely distributed, ranging between 139 and 1,281 persons per square mile for first to third quartiles of population density and between $10,000 and $12,500 for per capita income. Plants in this sample have a mean age of 27 years, mean wage of $26,000 a year, and mean local employment share of 8.5 percent.

The U.S. water pollution data come from a sample of 1,368 plants in EPA's NPDES data base that could be matched with the LRD. Here the matching counties are less densely populated: first and third quartiles range between 74 and 742 people per square mile. Per capita income is similar to that in the other data sets, with an interquartile range of $9,607 to $12,168. The plants have a mean age of 27 years and employ a mean of 4.1 percent of county workers at a mean annual wage of $26,000.

For Indonesia, out of a total sample of 253 plants, we have ownership information on 246. Three are wholly foreign owned, 13 are completely owned by the government, and 178 are owned by Indonesians. Factory age ranges from 0 years (2 firms) to 90 years (2 firms), with the median age of firms being 10 years. The geographic spread of the data is restricted to three islands—Java (189 plants), Sumatra (40 plants), and Kalimantan (24 plants)—and eight provinces. Forty-one International Standard Industrial Classification (ISIC) codes or sectors are represented in the data set, and firms range in size from 22 to 41,821 employees, with share in *kabupaten* employment varying from 0.02 to 91 percent. The *kabupaten* represented in the data are quite varied as well: 1990 population density ranges from 3.4 to 53,876 persons per square kilometer, the proportion of the population with more than a primary education varies between 6.85 and 48.5 percent, and mean annual per capita expenditure varies from Rp256,447 to Rp837,277 (1990 rupiah).

IV. RESULTS

The econometric results for Indonesia from Pargal and Wheeler (1996) are reproduced in table 1, while comparative results for the United States are reported in table 2. Because we regress log (emissions) on log (output), the regression coefficients should be interpreted as partial effects on pollution intensity.

Table 1. *Determinants of Pollution Intensity in Indonesia*

Variable	*Coefficient estimate*
Intercept	17.479**
	(2.38)
Economic variables	
Output	0.712***
	(3.78)
Wage	−0.316
	(0.52)
Fuel price	−1.267
	(0.52)
JAVA[a]	−1.530***
	(2.98)
Plant/firm variables	
Value added per worker	−0.312*
	(1.79)
Age	0.179
	(1.07)
Foreign ownership[b]	0.0004
	(0.06)
State ownership[b]	0.021***
	(2.91)
Textiles[b]	1.247***
	(3.41)
Leather tanning[b]	1.961***
	(3.14)
Food[b]	2.480***
	(4.52)
Pulp and paper[b]	2.265***
	(3.98)
Wood products[b]	−0.930
	(1.02)
Community variables	
Local employment share	−0.313*
	(1.84)
Income per capita	−2.811***
	(3.02)
Percentage of population with	−0.668
greater than primary education	(1.17)
Population density	0.128
	(0.62)
Number of observations	250
Adjusted R^2	0.3805

*Significant at 10 percent.
**Significant at 5 percent.
***Significant at 1 percent.

Note: The dependent variable is the log of biological oxygen demand (BOD) emissions volume in kilograms per day. Variables are in logs. *t*-statistics are in parentheses.

a. A dummy variable that is a proxy for the crude materials price.

b. Dummy variable.

Source: Pargal and Wheeler (1996).

Table 2. *Determinants of Pollution Intensity in the United States, 1987*

Variable	*Toxic emissions*	*Biological oxygen demand (BOD)*	*Total suspended solids (TSS)*	*Sulfur dioxide (SO_2)*	*Total suspended particulates (TSP)*
Intercept	6.18***	3.38	5.54	21.73	16.77
	(4.58)	(0.85)	(1.21)	(1.78)	(1.56)
Economic variables					
Output	0.69***	0.37***	0.50***	0.91***	0.88***
	(25.76)	(4.86)	(5.68)	(3.64)	(4.04)
Wage	0.84***	0.21	2.28***	-3.03	1.39
	(4.18)	(0.39)	(3.60)	(1.56)	(0.81)
Fuel price	-0.012	-0.09	-0.96**	4.48**	-0.13
	(0.10)	(0.27)	(2.52)	(2.69)	(0.09)
Plant/firm variables					
Value added per worker	-0.16***	-0.03	-0.14	0.94**	0.39
	(4.51)	(0.31)	(1.20)	(2.91)	(1.38)
Age	0.05	-0.11	-0.17	-0.31	0.42
	(0.83)	(0.50)	(0.66)	(0.50)	(0.76)
Textiles and leather[a]	1.77***	0.58	1.41***	2.11*	3.26***
	(13.16)	(1.53)	(3.24)	(1.72)	(3.02)
Wood products[a]	0.99***	-0.10	-0.02	-1.69	1.14
	(7.67)	(0.16)	(0.03)	(1.57)	(1.20)
Pulp and paper[a]	1.78***	2.98***	2.93***	0.78	-0.99
	(14.76)	(11.54)	(9.85)	(0.92)	(1.32)
Chemicals[a]	1.44***	-0.53**	0.16	1.62**	1.03
	(16.01)	(2.57)	(0.66)	(2.18)	(1.58)
Nonmetallic minerals[a]	0.51***	-1.64***	-0.48	1.01	3.53***
	(3.50)	(4.15)	(1.05)	(1.09)	(4.36)
Metals[a]	1.50***	-2.03***	0.11	-0.05	2.04**
	(13.02)	(8.13)	(0.39)	(0.06)	(2.69)
Machinery[a]	1.03***	-1.87***	-1.55***	-3.39***	-3.04***
	(11.78)	(8.54)	(6.14)	(4.49)	(4.58)
Miscellaneous	0.92	-1.33	3.38***	-1.10	-3.33
manufacturing[a]	(4.29)	(1.37)	(3.01)	(0.39)	(1.35)
Community variables					
Local employment share	0.08***	0.04	0.10	0.27	-0.34
	(3.28)	(0.58)	(1.17)	(1.10)	(1.56)
Income per capita	-0.59***	-0.51	-1.27**	-2.85**	-2.69**
	(3.58)	(1.08)	(2.35)	(1.90)	(2.03)
Population density	0.02	-0.04	-0.03	0.13	-0.43**
	(0.54)	(0.54)	(0.35)	(0.56)	(2.02)
Number of observations	11,827	1,343	1,343	869	869
Adjusted R^2	0.196	0.315	0.273	0.211	0.205

*Significant at 10 percent.
**Significant at 5 percent.
***Significant at 1 percent.

Note: Dependent variables are in logs of emissions volume. Toxic emissions, SO_2, and TSP are measured in pounds per year, and BOD and TSS are measured in kilograms per day. Variables are in logs. *t*-statistics are in parentheses.

a. Sectoral dummy variable.

Source: Authors' calculations.

The single exception is the result for log (output) itself, which should be reduced by 1 for interpretation in emissions-intensity form.

Standard Demand Variables

Among the standard demand variables, only scale economies emerge consistently in our results. In all cases except SO_2 in the United States, the output elasticity of emissions is significantly less than 1. Thus emissions intensity generally declines with plant output, reflecting scale economies of abatement.

The input price results show no consistent pattern of complementarity or substitutability with labor and energy across pollutants. For Indonesian BOD emissions, only the crude materials price proxy (JAVA in table 1) is significant. In the United States, there is evidence of emissions-labor substitutability for TSS and toxic emissions, emissions-energy substitutability for SO_2, and emissions-energy complementarity for TSS. Otherwise, cross-price effects are not significant. Within countries, labor and energy price variation seems to have had little effect on emissions intensity.

Firm- and Plant-Specific Variables

Except for sectoral differences, plant and firm characteristics show little evidence of consistent and significant impacts in these regressions. Value added per worker does have a negative, significant association with emissions intensity for the two variables that are not formally regulated: U.S. toxics and Indonesian BOD. For the formally regulated U.S. pollutants, however, the results for this variable are inconsistent. We find no effect for water pollutants (BOD and TSS), but a strong and significant positive association for SO_2. The association for TSP is also positive, although weaker. These results suggest a different balance in air and water emissions between pure efficiency effects and profitability from lower abatement costs. The effects of plant vintage are not strong, with some possible effect only for water pollution in Indonesia. This may not be too surprising, because even older facilities in the United States have operated under strict regulation for a long time.

Our results for sectoral dummy variables are generally consistent with expectations about relative pollution intensity. In the case of Indonesia, where five sectors are amply represented in the data set, our results show that four are more BOD intensive than other manufacturing sectors: textiles, leather tanning, food products, and pulp and paper. The BOD intensity for wood products is not significantly different from the average for other manufacturing. In the U.S. case, we include dummy variables for all two-digit SIC sectors, using food products as the excluded sector. This sector is known to have high intensity in organic water pollution (BOD) and relatively low intensity in toxics and standard air pollutants. Our results follow this pattern and indicate the following relative intensities for other sectors: textiles and leather, pulp and paper, chemicals, and metals have the highest intensity in toxics, while food products have the lowest; textiles, nonmetallic minerals (principally cement), and metals are the most intensive in TSP, while machinery and miscellaneous manufacturing are the least intensive; textiles and leather and chemicals are the most intensive in SO_2, while machinery is the least intensive. Not surprisingly, only pulp and paper are significantly more intensive in organic water pollution (BOD) than food products, although textiles and leather tanning are also relatively BOD intensive, as in the Indonesian case; metals and machinery are the least BOD intensive. Pulp and paper and miscellaneous manufacturing are the most intensive in TSS, while machinery is the least intensive.

To summarize, our results suggest that plant and firm characteristics are more important determinants of emissions intensity in weakly regulated economies than in strongly regulated ones. In the United States we find strong scale and sectoral effects, but no consistent effect for vintage and efficiency. However, the Indonesian results for vintage, efficiency, and public ownership are consistent with results obtained for Bangladesh, India, and Thailand in other studies (Huq and Wheeler 1993 and Hartman, Huq, and Wheeler 1997).

Informal Regulation or Community Variables

Our results suggest that informal regulatory forces are pervasive, even when strong formal regulation is in place. In both the United States and Indonesia, the elasticity of all emissions intensities with respect to community income is negative, large, and generally highly significant (the only exception is U.S. BOD). The estimated elasticity with respect to community income for the regulated U.S. air pollutants (SO_2 and TSP) is approximately equal to the elasticity for Indonesian BOD; U.S. water pollutants and toxic emissions have lower, but still substantial, elasticities. As discussed earlier, these results may reflect income-related differences in both preferences and power.

The income result is critical for our central hypothesis, and as previously noted there is some risk of upward bias in the estimated impact when per capita income is used as a proxy for local informal regulation. As might be expected, community income is highly correlated with community education in both countries. After controlling for income, education does not emerge as significant in either set of results. We reproduce the estimated coefficient for schooling in Indonesia but drop education from the final U.S. regressions.

The argument for endogeneity is based on co-location of poor communities with pollution-intensive industry sectors. By introducing sectoral dummy variables, our equations measure the impact of income on pollution intensity *after sector choices have been made.* As we noted in the previous discussion, our results confirm what is generally known about the relative pollution intensity of industry sectors. With the sector controls in place, our regressions allow us to focus on determinants of within-sector pollution abatement.

In an independent check for significant bias, we have analyzed the relationship between county income per capita and the location of the most highly polluting U.S. industry sectors. Using very different criteria, several empirical studies (Robison 1988, Tobey 1990, Mani 1996, Hettige and others 1994, and Mani and Wheeler 1997) have identified the same five three-digit SIC sectors as large outliers in air, water, and toxic pollution intensity: iron and steel (SIC 371), nonferrous metals (SIC 372), industrial chemicals (SIC 351), pulp and paper (SIC 341), and nonmetallic mineral products (SIC 369). For the year 1987 (the same year as our plant sample), we estimate a log-log function that relates per capita income in all U.S. counties to the ratio of value added in "dirty" production (our five outlier sectors) to value added in other manufacturing activities. In this context, there can be a serious problem of simultaneity bias *only* if the estimated effect of income on dirty-sector share is large and negative. However, our results (table 3) show no relationship at all. They reinforce our view that the econometric result in table 2 reflects the impact of income (and informal regulation) on in situ abatement, not location.

Results for the other two community-related variables in tables 1 and 2—plant share of local employment and population density—are mixed. Under informal regulation, there may be a significant "visibility effect" when polluting facilities can hide among other plants in urban/industrial areas. This would imply that population density should be positively associated with emissions intensity. When formal regulation ensures visibility by requiring emissions reports, however, another effect should dominate: more densely populated areas should exert pressure for greater cleanup because more people are adversely affected. This effect should be particularly strong for conventional air pollutants. In the United States, our results are consistent with this interpretation for TSP, the most visible air pollutant. However, no other U.S. pollutant has a significant relationship with population density. In the case of Indonesia, the positive association between BOD intensity and population density is consistent with a strong "visibility effect" in an unregulated economy, but the measured effect is weak.

Our results for plants' share of local employment are also mixed and have no ready interpretation. Under informal regulation, the estimated impact of relative size will reflect two considerations: the plant's visibility as a polluter and the benefits it brings to the community as an employer. In the United States, we would expect emissions reporting under formal regulation and, for toxics, the

Table 3. *County Income per Capita and Location of Pollution-Intensive Production in the United States, 1987*

Variable	*Coefficient estimate*
Intercept	−1.199
	(0.66)
Log (income per capita)	−0.17
	(0.88)
Number of observations	2,464
Adjusted R^2	−0.0001

Note: The dependent variable is log (VA_D / VA_O), where VA_D is value added in the five most pollution-intensive three-digit sectors, and VA_O is value added in all other manufacturing sectors. *t*-statistics are in parentheses.

Source: Authors' calculations.

TRI to reduce or eliminate the visibility effect. We might therefore expect the employment benefit effect to dominate, with larger employers having greater emissions intensity, other things being equal. This is indeed the case, particularly for toxics. The exception is the most visible pollutant, airborne TSP. This has a marginally significant negative association, as does informally regulated BOD in Indonesia.

V. Summary and Conclusions

In this article, we used plant-level data from the United States and Indonesia to test a model of equilibrium pollution under informal regulation. The model yields a reduced form in which emissions intensity is related to variables in three categories: standard demand variables (scale, input prices), plant and firm characteristics (sector, efficiency, vintage, ownership), and informal regulatory variables (community income, population density, plant size relative to local economy). We estimated emissions regressions for four formally regulated U.S. pollutants (TSP, SO_2, BOD, and TSS) as well as for unregulated pollutants (toxic pollution from U.S. factories and BOD emissions from Indonesian factories). Thus the full set of regressions also includes implicit controls for formal regulation and level of economic development.

Our results suggest three common elements across countries and pollutants: (1) abatement is generally subject to significant scale economies, (2) within-country variations in labor and energy prices have little impact on pollution intensity, and (3) community incomes have a powerful negative association with pollution intensity. Although the plant and firm characteristics we have measured seem important in Indonesia (and other Asian developing economies we have studied), only scale and sector have consistent, significant effects in the United States.

Our findings on community income are particularly important, because they suggest a powerful role for informal regulation whether or not formal regulation is in place. The impact of income disparity on intercounty differences in U.S. pollution intensities seems to match the impact in Indonesia. Undoubtedly, this reflects differences in both preference for environmental quality and ability to exert pressure on polluting factories. The fact that such disparities exist in the United States, even for traditionally regulated pollutants, shows that U.S. regulation has not been able to ensure uniform environmental quality for all citizens regardless of income.

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