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What Improves Environmental Compliance? Evidence from Mexican Industry

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This paper uses new survey evidence to analyze the effects of regulation, plant-level management policies, and other factors on the environmental compliance of Mexican manufacturers. In Mexico and other developing countries, many plants avoid complying with regulations because monitoring and enforcement are sporadic. On the other hand, some plants overcomply because their abatement decisions are strongly affected by extra legal factors. We attempt to capture both possibilities in a model of decision making under uncertainty: A plant minimizes expected pollution-related costs by setting emissions intensity (emissions/output) at the point where marginal abatement cost is equal to the expected marginal penalty for polluting. Compliance status is determined by the positive or negative gap between the regulatory standard and the plant's cost-minimizing emissions intensity. Among determinants of the latter, we focus particularly on environmental management policies: the degree of effort to reduce emissions, and the type of management strategy which is adopted. Recognizing that these policies and emissions are simultaneously determined, we use two-stage least squares for econometric estimation. Our results suggest that environmental management has a strong, independent effect on compliance, even after we control for simultaneity and take many other determinants of emissions intensity into account. We conclude that in developing countries with weak regulation, the carrot of subsidized environmental management training may provide a useful complement to the uncertain stick of conventional enforcement. © 2000 Academic Press

1. INTRODUCTION

Researchers in economics and management typically differ in their treatment of management decisions. Assuming that firms optimize with known production sets (including management techniques), economists prefer to analyze responses to exogenous changes in markets, regulations, and other variables. The conventional, if generally unspoken, view is that management practices are endogenous. Some

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management researchers, on the other hand, are comfortable with the assumption that managers have incomplete knowledge of production sets and techniques for optimization. This assumption validates empirical studies which relate management choices to differences in profitability.

Although we are economists, we adopt the management research perspective in this paper because the assumption of incomplete information seems appropriate. For plant and firm managers in developing countries, improved environmental performance implies experimentation with new production sets. In Mexico, for example, serious environmental regulation is largely a phenomenon of the 1990s. Both regulators and businesses are still adjusting to the environmental era, and there is considerable uncertainty about the relative effectiveness of alternative approaches to regulatory policy and plant-level environmental management. Under these conditions, the speed and magnitude of plants' response to regulatory incentives are not fixed parameters. Plant managers need specific kinds of information to respond effectively, and these are often scarce.

Because pollution is a damaging externality, this information gap may warrant a policy response. Of course, public resources should be used for development of efficient regulatory instruments. However, subsidized information and training may complement these instruments by increasing firms' responsiveness to regulatory incentives for pollution control. Pollution may be reduced more quickly by mixed strategies, which allocate significant resources to targeted information and training, as well as conventional monitoring and enforcement.

In this paper, we use new survey data from Mexico to study the role of environmental management systems (EMS) in plants' response to incentives for pollution control. Our econometric analysis extends the "equilibrium pollution" model of Pargal and Wheeler [22] in two ways. First, we test much broader hypotheses about the impact of plant or firm characteristics, markets, formal regulation, and "informal regulation" (or community pressure) on pollution control. Second, we embed EMS in the model to test the impact of environmental management on regulatory compliance, once other factors are taken into account.

We recognize that a positive correlation between regulatory compliance and stronger EMS does not imply a causal role for the latter. Many firms will change their environmental management practices when optimal pollution abatement levels are altered by exogenous changes in regulations or other factors. We use two-stage least squares to address this simultaneity problem. In the first-stage equations, we regress EMS indices on exogenous determinants of environmental compliance. Our EMS indices capture both relative effort to improve performance and the type of strategy adopted by the plant. We use the results to construct EMS instrumental variables, whose impact on regulatory compliance is tested in a second-stage equation. The results suggest a significant role for environmental management, even after correcting for endogeneity. In addition, they suggest that some approaches to EMS are more effective than others in promoting compliance.

The rest of the paper is organized as follows. In Section 2 we develop a model of equilibrium emissions and regulatory compliance under developing-country conditions. Section 3 introduces Mexico's regulatory system and uses the Mexico survey for a descriptive analysis of plant-level compliance. We present our econometric results in Section 4, along with simulations which explore their implications. Section 5 provides a summary and conclusions.

2. EQUILIBRIUM EMISSIONS AND REGULATORY COMPLIANCE

Recent research on developing economies in Asia has shown that many factories comply with environmental regulations, even when monitoring and enforcement are weak or nonexistent (Hettige *et al.* [15]; Hartman *et al.* [13]; Afsah *et al.* [3]. As we show in this paper, the same is true for Mexico. This result seems counterintuitive, since firms have no apparent incentive to comply with regulations which are not enforced. In some cases, public-spirited managers may deserve the credit (Sonnenfeld [25]; Reed [23]). More generally, however, unregulated firms reduce pollution because abatement incentives are provided by factors other than conventional enforcement. For example, the Asian research has suggested that local communities exact penalties through "informal regulation"—social, political and legal (Pargal and Wheeler [22]; Sonnenfeld [25]; Dasgupta and Wheeler [8]). A number of studies in North America, Latin America, and Asia have shown that bad environmental performance lowers the market valuation of firms and reduces banks' willingness to extend credit (Sonnenfeld [25]; Laplante and Lanoie [19]; Dasgupta *et al.* [7]; Lanoie *et al.* [17]; Hamilton [12]; Muoghalu *et al.* [21]; Shane and Spicer [24]). As we explain below, other factors such as firm ownership and market orientation may also affect plants' incentive to control pollution.

2.1. *Equilibrium Emissions Intensity*

Figure 1 provides a simple model of plant-level abatement in this context.[3] For the representative plant, cost-minimizing emissions intensity (pollution/output—P)

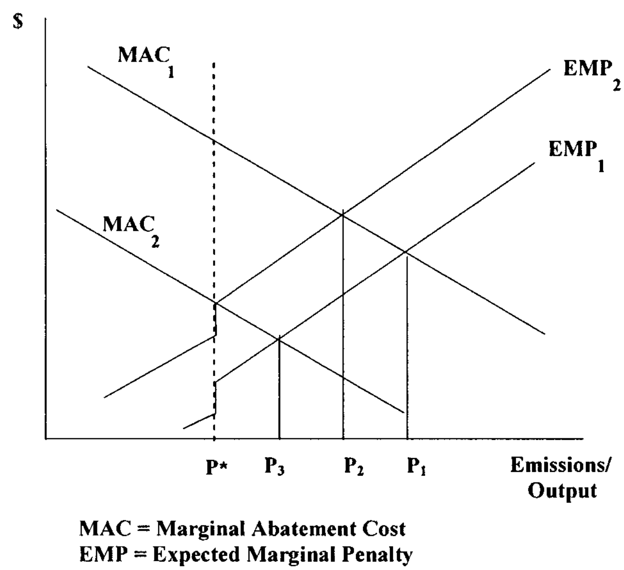

FIG. 1. Equilibrium emissions intensity.

[3]Recent work shows that a similar model is relevant for developed countries, although transactions costs are generally lower. For evidence from Canada, see Lanoie *et al.* [17] and Laplante and Rilstone [18].

is determined by the intersection of two marginal cost schedules.[4] The first is the expected marginal penalty (EMP) schedule, which increases with P. Part of the penalty is the sanction for failure to comply with the regulatory standard, P^*. This component is zero to the left of P^*, creating a discontinuity in the EMP schedule. Formal sanctions play an important role when the regulator can identify and prosecute most plants which fail to comply with regulations. Even where formal regulation is weak, however, plants must consider potential sanctions from local communities and market agents (see Section 2.3). The second schedule reflects the plant's marginal abatement cost (MAC). In Fig. 1, it slopes upward to the left. Possible determinants of MAC (discussed in Section 2.3) include plant size, firm size, process technology vintage, human resources, and the quality of environmental management.

2.2. *Policy Options*

A two-period exercise is sufficient to illustrate the policy implications of the model. In Period 1, the plant's cost-minimizing emissions (P_1) are determined by the intersection of MAC_1 and EMP_1. At this point, the plant's emissions intensity far exceeds the regulatory standard (P^*). Despite the plant's gross noncompliance, the regulator's weakness guarantees a low probability of identification and/or a low expected fine.

In Period 2, a budget increase gives the regulator two options. The first is increased monitoring and enforcement, moving the EMP schedule inward to EMP_2. In the new cost-minimizing equilibrium, the plant's emissions drop to P_2, the intersection of MAC_1 and EMP_2. The regulator's second option is a resource-equivalent program to train plant managers in environmental management systems (EMS). To illustrate the potential impact, we assume that EMS training shifts the plant's marginal abatement cost schedule to MAC_2. Regulatory monitoring and enforcement remain at the original level, so the plant's expected marginal penalty schedule is still EMP_1. In this case, however, the inward movement of the MAC schedule more than compensates for the stationary EMP schedule. Equilibrium emissions intensity falls to P_3 (the intersection of MAC_2 and EMP_1), which is substantially below P_2 and much closer to the regulatory standard.[5] In this scenario, EMS training is more cost-effective than conventional strengthening of regulatory monitoring and enforcement, because training promotes greater emissions reduction without significant countervailing economic distortions.

This illustration suggests that publicly supported EMS training may be cost-effective in some cases. Two other considerations reinforce its appeal under developing-country conditions. The first is corruption of inspectors in conventional en-

[4] We use emissions intensity for simplicity of exposition. In practice, regulatory standards include both mandated pollution/output and mandated effluent concentration (pollution per unit volume of the waste stream).

[5] Another option, not explored in this paper, is use of public resources to provide better public information about polluters. Recent experience with public disclosure in the OECD (Tietenberg and Wheeler [26] and developing countries (Afsah *et al.* [2]) suggests that better-informed communities can move EMP significantly to the left by increasing local social, political and legal pressure on plant managers. In fact, evidence from Pargal and Wheeler [22], Sonnenfeld [25], and Afsah and Vincent [4] suggests that this option may actually shift P_3 to the left of P^* (performance which exceeds compliance requirements) for plants which are highly sensitive to environmental reputation.

forcement regimes. While attempts to reinforce the "stick" of enforcement may be defeated by corruption, the "carrot" of subsidized EMS training carries no such risk. The second potential advantage of EMS training relates to import dependency in many developing economies. Indonesia's current crisis provides a good illustration of the problem. Rapid devaluation of the rupiah has dramatically increased the price of imported inputs for end-of-pipe pollution control, moving MAC outward for Indonesian plants. At the same time, EMP has moved outward because falling tax revenues have decimated regulatory budgets. Equilibrium pollution intensity should therefore have increased—a result consistent with Indonesian data cited by Afsah [1] in a recent paper.[6]

In such a case, it is useful to contrast long-run outcomes in Fig. 1 when business cycle effects are taken into account. The inward shift of EMP promoted by a budget increase will be reversed by budget cuts in the downturn. After EMS training, however, the new knowledge is embodied in plant operations. This knowledge will persist in an economic downturn, so inward movement of the MAC schedule induced by EMS training will not be reversed by a devaluation (unless, of course, the managers are foreigners who must be paid in dollars). The outward shift of the EMP schedule will still increase equilibrium emissions intensity, but (in general) less than in the previous case. Thus, resistance to business cycle effects may increase the advantage of subsidized EMS assistance.

2.3. *Modeling Equilibrium Emissions*

Marginal Abatement Cost Function

In our model, the "price" of pollution is the expected marginal penalty (EMP) which the firm will have to pay at each level of emissions intensity. It is useful to view EMP as the expected price of environmental services which are used by the plant, along with inputs of capital, labor, energy, and materials. Diminishing returns apply, so reduction in the use of any input (including environmental services) implies rising marginal costs. For pollution intensity, this generates the MAC schedule in Fig. 1.

The MAC function may be sensitive to a variety of plant and firm characteristics. Scale economies in abatement mean that large plants will have lower MAC than small plants at identical emissions per unit of output (Dasgupta *et al.* [6]; Dasgupta *et al.* [9]). Factories in a multiplant firm may also have lower MAC, since the parent firm should be able to spread the cost of higher-level technical services over more units. Different sectors have very different abatement problems, so we would expect MAC to vary by sector. Plants with newer process technologies may also have lower MAC, since newer technologies may generate fewer polluting residuals than processes designed before the environmental era. Plants with more educated workers and experienced managers may run more efficiently and confront lower MAC than their counterparts. Finally, we expect the degree and quality of environmental management system (EMS) implementation to have a significant impact on MAC (see Section 3).

[6] Our thanks to Shakeb Afsah for useful discussion of this issue.

To summarize, we specify the MAC function for the ith plant in the jth industry sector

$$\text{MAC}_{ij} = f(P_i, Q_i, D_i, S_j, V_i, N_i, X_i, E_i), \qquad (1)$$

where the arguments of the function are, respectively, indices of emissions/output (P), plant size (Q), multidivisional status (D), sector (S), age of process technology (V), workers' schooling (N), general management experience (X), and quality of environmental management (E).

Expected Marginal Penalty Function

In our model, the plant does not face a single price of pollution. Rather, it confronts an expected marginal penalty function which increases with emissions per unit of output. The position and slope of the EMP function may be affected by several characteristics of the plant, its parent firm, related market agents, and its local environment. One important factor may be the plant's own experience with regulatory inspections and enforcement. The strength of informal regulatory activity by local communities may also be a significant determinant of EMP. Following Tietenberg and Wheeler [26], we hypothesize that pressures from financial and product markets may play significant roles. Ownership may also be important. The public generally has more information about publicly traded firms than family-owned firms, including environmental information. Public preference for a cleaner environment may therefore register more strongly on publicly traded firms. Market links to the OECD economies may also be significant in this context. Green consumerism may impart greater sensitivity to export-oriented plants. Anecdotal evidence cited in Birdsall and Wheeler [5] suggests that multinationals may have greater sensitivity to environmental risk in Latin America. However, recent econometric research on data from large samples of Asian plants has not shown a significant role for multinational ownership (Pargal and Wheeler [22]; Hartman *et al.* [13]).

To summarize, we hypothesize the expected marginal penalty function for the ith plant,

$$\text{EMP}_i = f(P_i, A_i, C_i, O_i, T_i), \qquad (2)$$

where the arguments of the function are indices of emissions/output (P), formal regulatory activity (A), local community action (C), ownership (O), and trade links (T).

Equilibrium Emissions

For a polluting factory, cost-minimizing emissions/output will be determined at the point where MAC = EMP. Combining and rearranging Eqs. (1) and (2), we obtain the reduced form expression for emissions intensity in the ith plant,

$$P_i = f(Q_i, D_i, S_j, V_i, N_i, X_i, E_i, A_i, C_i, O_i, T_i). \qquad (3)$$

Although sector effects (S) are variable, most of the associated derivatives have signs which can be predicted from the model. We expect negative marginal effects for plant size (Q), multidivision status (D), worker's education (N), managers' general experience (X), level and quality of EMS (E), formal regulatory activity (A), local community action (C), publicly traded status (O_1), multinational ownership (O_2), and export links to the OECD (T). Conversely, we expect process technology age (V) to have a positive marginal effect on emissions/output.

3. INDUSTRIAL POLLUTION AND REGULATION IN MEXICO

During the past 40 years, Mexico has built one of the largest industrial economies in the developing world. Until recently, however, environmental regulation has received scant attention. The result for Mexico City has been air pollution which is among the worst in the world. Concentrations of airborne fine particulates, for example, exceeded the legal safe standard in 98 days during 1995 and 182 days during 1996 (DDF [10]). Other cities are also suffering from excessive pollution.[7]

3.1. *Environmental Regulation*

At the national level, an institutional response to this problem began in the late 1980s and has accelerated during the past few years. In its first phase of development, the national regulatory system has had two prominent characteristics. The first is an emphasis on command-and-control regulation, in which polluters are evaluated according to compliance with numerous licenses and permits issued to each plant. The second characteristic has been multi-institutional administration. Different aspects of industrial pollution control have been the responsibility of different agencies within the *Secretaría del Medio Ambiente, Recursos Naturales y Pesca* (SEMARNAP). A particularly important role is played by the *Procuraduría Federal de Protección al Ambiente* (PROFEPA), which is charged with factory inspections and enforcement of all pollution regulations. During the 1990s, PROFEPA has expanded its activities from a few inspections per year to several thousand.

Mexican environmental policy continues to evolve rapidly, reflecting rising consciousness of pollution problems and Mexico's higher international profile (e.g., negotiations to enter NAFTA and the OECD). In April 1997, President Zedillo introduced a new approach to pollution control, which is intended to promote Mexico's interest in both international competitiveness and strong environmental protection. It will integrate regulation of emissions to air, ground, and water; stress cost-effective regulatory instruments; permit much broader public access to environmental information; and operate from an integrated information system which will employ all the data resources of SEMARNAP.

For the purposes of this paper, two aspects of Mexico's recent pollution control experience are most important. First, the system is quite new. Many Mexican factories have not yet been inspected, although PROFEPA's activities are widely known. Second, business managers in Mexico now acknowledge that they will have to respond to stricter environmental standards. Our survey of Mexican industry therefore provides a snapshot of an industrial system in transition. Faced with credible evidence of the government's intent to regulate more strictly, Mexican

[7] Detailed air quality data for Mexico's major urban areas can be found on SEMARNAP's Website: http://www.ine.gob.mx/indicadores/ingles/i_5.htm.

TABLE I

Sectoral and Size-Class Distribution of Plants Surveyed

	Sector			
Size[a]	Food	Chemicals	Nonmetallic minerals	Metals
Large	21	18	12	20
Medium	22	21	12	18
Small	19	23	27	23

[a]Size classes are defined by employment ranges as follows: small (16–100 employees); medium (100–250); large (250 +)

firms have begun experimenting with new approaches to environmental management and training.

3.2. *The National Survey of Industrial Polluters*

The data used for this paper were produced by a large survey of Mexican manufacturers carried out in the fall of 1995.[8] The survey focused on four sectors which are estimated to generate between 75% and 95% of Mexico's total industrial pollution: food, chemicals, nonmetallic minerals, and metals. Confidential, in-depth interviews were conducted at 236 facilities, chosen to represent Mexican factories in a set of categories defined by sector, size class, and location. Tables I and II provide information on the distribution of plants surveyed. Summary information on other variables can be found in Appendix 1.

The survey was designed by a World Bank team which included the authors. It was conducted by the Monterrey Institute of Technology (MIT), with the explicit support of Mexico's National Environment Ministry (SEMARNAP) and the Mexican National Association of Industries. To minimize reporting bias, the survey was conducted only after agreement by all sponsors (the government, the bank and the Industries Association) that the MIT team would not reveal the identity of the plants surveyed or the respondents within the plants.

The survey provides very detailed information about regulatory compliance and the determinants of the plants' marginal abatement cost (MAC) and expected marginal penalty (EMP) schedules. Factors which are theoretically related to MAC include plant size, multidivision status, sector, technology vintage, human resources, and experience with environmental management systems. Determinants of expected marginal penalties include experience with formal regulation (inspections), informal regulation (relationship with the local community), ownership (publicly traded vs family owned) and international links (multinational ownership, trade links with OECD economies).

Our analysis relies solely on self-reported compliance, since we had no access to independently audited data on pollution and regulatory compliance. Is self-assessed performance a credible measure? Useful evidence is provided by Table III,

[8]Both the survey questionnaire (in Spanish) and the data are available online at http://www.worldbank.org/nipr/work_paper/1877/survey/index.htm.

TABLE II
Regional and Sectoral Distribution of Plants Surveyed

Region	Sector: Food	Chemicals	Nonmetallic minerals	Metals
Medium city	21	20	18	21
Industry corridor[a]	19	20	9	21
Large city	22	22	24	19

[a]An industrial area which extends between two urban regions

which summarizes the respondents' overall assessment of their facilities' compliance with Mexican regulations.

With confidentiality reasonably well assured, 49% of survey respondents replied that their plants were not in compliance with regulations.[9] Only 10% rated their facilities as Excellent, and 7% as Poor or Very Poor. We have no benchmarks, so we can only make an educated guess about the degree of upward bias in this self-assessment. Suggestive evidence is provided by recent research on Indonesia, a country with similar regulations but much weaker monitoring and enforcement. Independent auditing of a large sample of Indonesian plants has shown that approximately 64% are noncompliant (Afsah and Vincent [4]), with 3% in the "extremely damaging" category. This evidence suggests that the degree of upward bias in the Mexican self-assessment may not be large. In any case, our analysis focuses on relative, not absolute, performance. Independent assessment of conditions in the surveyed plants by the MIT team indicated a high correlation between self-assessment and observable conditions.

TABLE III
Self-Assessed Compliance

Environmental performance	Number of plants	% of total
Excellent: far more than necessary for compliance	23	10
Good: almost always in compliance	96	41
Fair: occasionally compliant	99	42
Poor: never in compliance	10	4
Very poor: far below compliance; very damaging	8	3

[9]The stochastic nature of emissions implies that they will occasionally fall within acceptable bounds, even if a factory's general pattern of emissions is clearly out of compliance with the regulatory norm. When we designed the survey, we intended the category "occasionally compliant" to cover such cases. Both the surveyors and the respondents understood the meaning of the category. Respondents who used this classification were, in fact, stating that their factories were noncompliant according to conventional regulatory standards as applied by Mexican inspectors.

3.3. *Environmental Management Variables*

This paper focuses particularly on the measures of environmental management (E_i) in Eq. (3). We have used the survey information to define two indices of management effort: adoption of ISO 14001—type environmental management procedures; and expanded use of personnel for environmental inspection and control. To study the effect of alternative strategies, we have also defined two indices of "mainstreaming": assignment of environmental responsibilities to general managers, rather than specialized environmental managers; and general environmental training for plant employees, as opposed to training focused on environmental specialists.

The rationale for one of our effort indices seems clear: Expanded use of personnel for environmental inspection and control reflects the standard logic of resource reallocation when relative prices change. However, the other indices require more explanation.

ISO 14001 *Sequence*

Why should a "workbook" approach to environmental management yield better performance? In general, workbook exercises will improve overall understanding and performance only if they induce appropriate learning. In the case of ISO 14001, the basic exercises are defined as follows:[10]

1. an initial review by management to identify environmental issues of concern (e.g., excessive use of polluting inputs, the potential for a serious environmental accident);
2. establishment of priorities for action, taking into account factors such as local environmental regulations and potential costs;
3. establishment of an environmental policy statement, to be signed by the CEO;
4. development of performance targets based on the policy statement (e.g., 50% reduction of heavy metals emissions by some future date);
5. implementation of an environmental management system as part of reaching the performance targets;
6. implementation review; performance measurement.

Following the ISO 14001 sequence will not, of course, guarantee any improvement in environmental performance. However, it seems likely that plants which complete these steps will be informed, organized, and motivated in ways which distinguish them from other facilities. Table IV provides a summary of current practice in our sample, as defined by survey questions which reflect the ISO 14001 principles. We use an adoption score (AS) scaled 0–100 to index the completeness of plants' environmental management systems. As Table IV shows, the sample plants vary widely. Almost half have scores below 25; about 18% have relatively complete systems (75–100); and about 35% are intermediate.

[10] See Appendix 2 for a more detailed discussion.

TABLE IV
Adoption of ISO 14001-Type Procedures

Adoption score	Number of plants	Percent
$AS \leq 25$	111	47.0
$25 < AS \leq 50$	45	19.1
$50 < AS \leq 75$	38	16.1
$75 < AS \leq 100$	42	17.8

Mainstreaming vs Specialization

From a theoretical perspective, neither mainstreaming nor specialization is clearly optimal under all conditions. The argument for specialized training and management seems strongest for cases where environmental problems are technically complex, concentrated at a few points, and separated from standard production processes. However, in real-world cases this potential advantage may never be greater than the benefits from mainstreaming. Table V shows that our sample plants are pursuing different options: Only 6% have specialized environmental managers, while 67% have specialized environmental training. It is possible to reconcile these data with a model of optimization, but it seems more plausible to regard Table V as a snapshot of experimentation in a transitional era. We will return to this issue in our discussion of the results.

3.4. *Survey Results*

Before turning to the formal econometric analysis, we provide a summary of the survey results in Tables VI–X. We focus on self-assessed compliance status, since we have no direct observations on plant-level emissions intensities (emissions/output). However, the logic of Fig. 1 suggests a reasonably close relationship between the degree of compliance and emissions intensity. Plants whose equilibrium emissions intensities are far to the right of P^* should have serious compliance problems, while those in the vicinity (or to the left) of P^* should generally be in compliance.[11] Tables VI–X show the bivariate relationships between compliance and the hypothesized determinants of the MAC and EMP schedules in our model.

TABLE V
Mainstreaming vs Specialization

	Yes	%	No	%
Environmental training for nonenvironmental workers?	76	32.6	157	67.4
Environmental manager also has other responsibilities?	211	93.8	14	6.2

[11] Emissions can be highly variable, even over relatively short periods of time. Key determining factors include equipment maintenance, the incidence of accidental releases, changes in material inputs, etc. Even "clean" plants may sometimes violate regulatory standards, while their "dirty" counterparts may occasionally comply with them.

TABLE VI
MAC Determinants: Compliance Status by Size, Firm Type, and Sector

	Plant size		Firm type		Sector			
	Small	Large	Multi-plant	Single plant	Food	Chemicals	Metals	Nonmetallic minerals
Compliant	42	42	72	34	30	36	25	28
Noncompliant	50	29	49	64	32	26	36	23
Total plants	92	71	121	98	62	62	61	51
% compliant	45.7	59.2	59.5	34.7	48.4	58.1	41.0	54.9

MAC Determinants

Tables VI–VIII present evidence on bivariate relations between compliance and the hypothesized determinants of marginal abatement cost: "structural" variables (plant size, multidivisional status, sector); resource variables (technology vintage, percentage of workers with secondary education, presence of managers with international experience); and indices of environmental management (expanded use of environmental personnel; management and labor mainstreaming; EMS adoption).

The structural variables all exhibit strong bivariate relationships (Table VI). Large plants are markedly more compliant than small ones (59% vs 46%); facilities in multiplant firms outdistance their counterparts (60% vs 35%); and sectors vary significantly (from a high of 58% for chemicals to a low of 41% for metals). The results for the resource variables (Table VII) are less striking and, in fact, perverse for vintage: The oldest plants in the sample are more compliant than the newest plants, ceteris paribus (52% vs 43%). The effect of workers' secondary education on compliance is positive, as expected, but not strong (51% vs 46%). However, we observe a much stronger relationship for managers' international experience (64% vs 40%).

TABLE VII
MAC Determinants: Compliance Status by Technology Vintage and Human Resources

	Percentage of plant installed since 1990		Percentage of employees with secondary education		Managers have international experience	
	20% or less	80% or more	Less than 50%	More than 50%	Yes	No
Compliant	61	46	70	37	48	59
Noncompliant	57	60	82	35	27	89
Total	118	106	152	72	75	148
% Compliant	51.7	43.4	46.1	51.4	64.0	39.9

TABLE VIII
MAC Determinants: Compliance Status by EMS Experience

	Expanded env. personnel?		Management mainstreaming?		Labor mainstreaming?		Adoption score for EMS		
	Yes	No	Yes	No	Yes	No	25 or less	25 to 75	More than 75
Compliant	74	31	10	95	70	34	26	45	36
Noncompliant	54	61	4	108	49	65	73	38	6
Total	128	92	14	203	119	99	99	83	42
% compliant	57.8	33.7	71.4	46.8	58.8	34.3	26.3	54.2	85.7

The EMS variables have the strongest apparent impact as a group (Table VIII). Plants which have expanded environmental personnel report much higher compliance than others (58% vs 34%). The same is true for plants which have mainstreamed environmental concerns for management and labor (71% vs 47% for management; 59% vs 34% for labor). However, the most striking relationship links compliance and EMS adoption: Compliance ranges from 26% for the lowest-scoring group to 86% for plants which have high scores, with 54% compliance in the middle group.

To summarize, the results in Tables VI–VIII suggest the strongest associations for EMS indices, followed by the structural variables. Our results suggest that compliance is highest for large plants which are part of multidivisional firms, managed by people with international experience, and strongly committed to expanded environmental personnel, environmental mainstreaming and the adoption of EMS. Conversely, employee education does not raise compliance much and technology vintage seems to have a perverse impact.

EMP Determinants

Tables IX–X present evidence on bivariate relationships between compliance and the hypothesized determinants of the plant's expected marginal penalty (EMP) function: indices of formal regulation, informal regulation, ownership, and trade

TABLE IX
EMP Determinants: Compliance Status by Formal and Informal Regulatory Experience

	Formal regulatory requirements significant influence?		Subjected to inspection?		Local community a significant influence?	
	No	Yes	No	Yes	No	Yes
Compliant	17	80	15	89	66	23
Noncompliant	23	80	17	96	78	26
Total	40	160	32	185	144	49
% compliant	42.5	50.0	46.9	48.1	45.8	46.9

TABLE X

EMP Determinants: Compliance Status by Ownership and Multinational Links

	Ownership		Ownership		% of sales to OECD	
	Multi-national	Domestic	Family owned	Publicly traded	Below average (= 14%)	Above average
Compliant	10	96	49	43	73	34
Noncompliant	9	104	72	31	88	29
Total	19	200	121	74	161	63
% compliant	52.6	48.0	40.5	58.1	45.3	54.0

links. The survey includes two questions related to formal regulatory experience: the influence of regulatory requirements, and whether or not the plant has ever had an inspection. As Table IX shows, most plants (80%) report a strong influence for regulatory requirements, and at least one inspection (85%). Plants with high regulatory influence have somewhat higher compliance (50% vs 43%) than their counterparts. No difference is observable for inspection experience (48% vs 47%). Our measure of informal regulation does not fare well, either. A minority (25%) of plants report significant community influence, and their compliance is not significantly better than their counterparts' (47% vs 46%).

Table X displays the survey results for variables related to ownership and international links. In Section 2, we hypothesized that better public information should make publicly traded firms more sensitive to environmental issues than family-owned enterprises. The bivariate results are consistent with this hypothesis: 58% of publicly-traded firms are compliant, vs 41% of family-owned firms. A priori, it also seems reasonable to suppose that reputation effects will pressure internationally oriented firms toward compliance. However, the survey evidence does not provide strong support: Multinational affiliates are only modestly better than domestic firms (53% vs 48%); the relationship is stronger for plants (regardless of ownership) with above-average OECD trade links (54% vs 45%).[12]

To summarize the bivariate results for EMP, only publicly traded firms exhibit a compliance differential as large as those of several MAC determinants (e.g., size, multidivision status, sector, manager's international experience, environmental management variables). Formal regulatory influence and OECD trade links have some association with compliance, while multinational ownership, informal regulation and prior inspections have no apparent impact.

4. ECONOMETRIC RESULTS

While the bivariate results in Tables VI–X are interesting and suggestive, they are undoubtedly affected by multicollinearity and simultaneity problems. Plant size,

[12] These results reflect previous results for Asia (Hartman *et al.* [13]; Pargal and Wheeler [22]; Hettige *et al.*, [15]).

for example, is correlated (0.40) with multiplant status. And, as we noted previously, EMS variables are determined simultaneously with emissions intensity (and compliance). If stronger regulation induces a plant to reduce pollution, greater EMS effort will probably be part of the response. Correlation does not necessarily imply causality, however: The impact of EMS will clearly be overestimated in a bivariate approach.

To address the simultaneity problem, we recast Eq. (3) into a two-stage system. In the first stage, we estimate reduced form equations which relate the environmental management indices to the other variables in Eq. (3):

$$E_i = f(Q_i, D_i, S_j, V_i, N_i, X_i, A_i, C_i, O_i, T_i). \tag{3a}$$

The second-stage equation relates compliance to the instrumented E_i's and determinants of plant-level abatement cost:

$$R_i = f\left(\hat{E}_i, Q_i, S_j, V_i, N_i, X_i\right). \tag{3b}$$

4.1. *First-Stage Equations*

Our four first-stage regressions are specified in the variables (corresponding variables from Eq. (3a) are noted in parentheses)[13]

$$\begin{aligned}\text{MGT} = f(&\text{SIZE}(Q), \text{MULTIDIV}(D), [\text{FOOD, CHEMICALS, METALS}](S),\\ &\text{TECH}(V), \text{EMPHIGH}(N), [\text{RULES, INSPECT}](A), \text{INFORMAL}(C),\\ &[\text{PUBLIC, MULTINAT}](O), [\text{BUSINESS, OECD, MEXICO}](T)),\end{aligned}$$

where the four MGT indices are defined as follows:

EMS—adoption score for EMS (see 3.3);

LABOR—significant assignment of workers to environmental work? (1 if yes);

MGT—environmental manager also assigned to other work? (1 if yes);

TRAINING—is environmental training given to nonenvironmental workers? (1 if yes).

The righthand variables are:

SIZE—sequential categorical variable (1 if employment 16–100; 2 if 100–250; 3 if greater than 250)[14];

MULTIDIV—whether the plant is part of a multidivisional firm (1 if yes);

FOOD, CHEMICALS, METALS—dummy variables for the Food, Chemicals, and Metals sectors;

[13] International management experience (X) and employee secondary education were tested in initial runs, but were never found to be significant.

[14] To assure confidentiality, the survey only asked for plant size within these ranges. In preliminary regression runs, we used dummy variables to test for discontinuities in plant size effects. However, the estimated dummy variable parameters could not be distinguished statistically from the relative weights implied by the use of a single variable coded "1-2-3." We have therefore adopted the latter for simplicity.

TECH—proportion of equipment acquired since 1990;

EMPHIGH—proportion of employees with postsecondary education;

MGTSEC—is secondary education the highest attained by the plant's senior manager? (1 if yes);

RULES—degree of influence of regulatory policies (0 (None) to 5 (High));

INSPECT—has the plant been subject to a regulatory inspection? (1 if yes);

INFORMAL—degree of influence of neighbors and community (0 (None) to 5 (High));

PUBLIC—proportion of the firm which is publicly traded;

MULTINAT—dummy variable (1 if multinational);

BUSINESS—degree of influence of clients and industrial association (0 (None) to 5 (High));

OECD—share of plant's shipments going to OECD countries;

MEXICO—share of plant's shipments going to Mexican destinations.

Table XI provides a summary of the first-stage estimates. The first column for each management index provides full regression results; the second includes only variables which remained significant after progressive deletion of insignificant variables. The linear EMS equation provides the most robust fit to the data (adjusted $R^2 = 0.40$ in the final form). The final forms of the three probit equations (LABOR, MGT, TRAINING) have pseudo-R^2's of 0.10, 0.18 and 0.14, respectively. Although these are relatively low, the robust Chi-square statistics show that the model variables have significant explanatory power. Our most striking result is a negative one: Most of the variables with some plausible claim to influence have no significant effect. These include all variables indexing OECD linkages (through ownership, trade, training, or management experience), technology vintage, and indirect community pressure (other than through formal regulatory actions).

The absence of any significance for foreign ties contradicts the conventional wisdom, but it is consistent with results of plant-level analyses in Asia (Pargal and Wheeler [22]; Hettige *et al.* [15]). We also find no significant differences for factories with more modern technology. Finally, we are interested to note that plants which report greater community pressure (as opposed to formal regulatory pressure) do not exhibit greater environmental effort than their counterparts. Recent work on Southeast Asia (Pargal and Wheeler [22]; Hartman *et al.* [13]) has suggested that local community characteristics such as income and education have a significant effect on the environmental performance of neighboring factories. Plentiful anecdotal evidence suggests that richer, more educated communities can pressure factories to control pollution. However, the Asian research has not been able to distinguish between local actions which are "formal" (i.e., part of local regulatory procedures) and "informal" (e.g., negotiations with community groups). The Mexican data are significantly more detailed, and suggest that local influence is working principally through local regulation.

Variables which *are* significantly associated with environmental management effort (EMS, LABOR) include plant size, multidivision status, postsecondary education, formal regulation, and public trading of the firm's stock. EMS has more significant determinants than the other management indices. The results for plant

TABLE XI
First-Stage Regression Results

Variable	EMS	EMS	LABOR	LABOR	MGT	MGT	TRAINING	TRAINING
SIZE	7,883	14.553	−0.126		−0.734	−0.685	0.287	0.305
	(2.559)	(5.81)[a]	(0.812)		(1.836)	(3.082)	(1.737)	(2.586)
MULTIDIV	14.823	15.953	0.307		0.441		0.222	
	(3.126)	(3.98)	(1.313)		(0.816)		(0.874)	
FOOD	−4.687		0.370		−0.394		−0.342	
	(0.768)		(1.208)		(0.564)		(1.049)	
CHEMICALS	1.608		0.263		0.270		−0.104	
	(0.265)		(0.870)		(0.390)		(0.325)	
METALS	−3,738		−0.186		−0.280		−0.415	
	(0.592)		(0.579)		(0.397)		(1.164)	
TECH	−0.038		−0.083		0.177		−0.027	
	(0.026)		(1.091)		(0.912)		(0.332)	
EMPHIGH	0.240	0.215	0.008	0.008	−0.004		0.003	
	(2.801)	(3.349)	(1.824)	(1.972)	(0.504)		(0.590)	
MGTSEC	24,355		0.325		**		**	
	(1.711)		(0.443)					
RULES	4.771	4.367	−0.007		−1.039	−0.307	0.110	
	(3.035)	(3.674)	(0.090)		(1.891)	(1.740)	(1.289)	
INSPECT	18.164		0.604	0.855	**		0.514	
	(2.878)		(1.824)	(2.919)			(1.237)	
INFORMAL	0.258		0.060		−0.027		0.015	
	(0.174)		(0.800)		(0.175)		(0.196)	
PUBLIC	0.105		0.005	0.005	0.005		0.009	0.009
	(2.184)		(2.108)	(2.433)	(0.974)		(3.542)	(4.586)
MULTNAT	−7.382		−0.168		**		0.489	
	(0.925)		(0.426)				(1.173)	
BUSINESS	1.892		−0.023		0.266		−0.081	
	(0.977)		(0.232)		(1.195)		(0.792)	
OECD	0.166		0.009		0.002		0.011	
	(0.795)		(0.850)		(0.147)		(0.998)	
MEXICO	0.250		−0.001		0.003		0.010	
	(1.419)		(0.150)		(0.234)		(1.153)	
CONSTANT	−47.359	−20.810	−0.876	−1.187	6.711	4.424	−3.170	−1.425
	(2.430)	(3.485)	(0.863)	(3.829)	(2.059)	(4.368)	(2.954)	(5.635)
Adj. R^2	0.38	0.40	0.14	0.10	0.26	0.18	0.19	0.14
F-Statistic	7.89	35.79						
Prov > F	0.0000	0.0000						
Chi-squared			32.91	24.08	15.40	18.93	41.49	35.64
Prob > chi-sq.			0.0076	0.0000	0.2828	0.0001	0.0003	0.0000
Observations	178	209	174	178	129	225	173	206

[a] t-statistics in parentheses.
**Use of variable infeasible with probit (spurious perfect prediction).

size and multidivision status are consistent with a lowering of unit costs as lumpy environmental resources are spread across more units of activity. Regulation by national and local authorities also seems to be making a difference in Mexico. We attribute the significance of worker education to greater efficiency in responding to new environmental incentives. LABOR is also affected by employee education, as well as publicly traded status. The latter effect suggests that public information provides an additional incentive to improve environmental performance.

An even smaller set of variables is significantly associated with orientation toward mainstreaming (MGT, TRAINING). Plant size has countervailing effects. The positive, significant impact of size on TRAINING suggests that larger plants have significantly more environmental training for nonenvironmental workers.[15] However, the negative, significant impact of size on MGT suggests that they also tend to assign environmental responsibility to specialized managers. Publicly traded plants are significantly more oriented toward mainstreaming labor. Plants which report significant regulatory influence seem to have more specialized environmental managers, but this is not a strong result.

4.2. *Second-Stage Equation*

Our second-stage analysis studies the relative impact of environmental effort and mainstreaming on environmental performance. A priori, we would expect better performance in plants which use more personnel for environmental monitoring and inspection. However, we are agnostic about whether adherence to a set of environmental management routines can, in itself, produce better performance. We have good information about the degree to which plants have implemented ISO 14001–type procedures, so we are able to test this proposition directly.

We are also interested in the impact of alternative strategies for training and assignment of responsibilities for environmental management. We use our information to investigate two questions about mainstreaming: First, for equivalent resources, is environmental performance improved more by training a specialized cadre of environmental workers or by spreading the training resources across all workers? Second, is it better to assign managers to the specialized task of environmental improvement, or is it better for line managers to assume environmental management as one of several tasks? In each case, it is possible to construct arguments for and against these propositions.

In the second-stage analysis, we estimate a probit equation which relates self-assessed compliance with environmental regulations to the four management indices, and several proxies for plant-level abatement cost: sector, plant size, vintage, and general worker education. The four management policy variables are

[15] As a referee has noted, this result may reflect a more general relationship: Larger plants may provide more formal training in all areas of concern, including environmental problems. Without broader survey data, we cannot test the effects of plant characteristics on general employee training. Our conclusions would not be altered by the existence of a positive relationship between plant size and general training. However, there might be interesting implications for training subsidies. Large plants may use formal training to compensate for educational deficiencies in the labor force (documented in Appendix 1). If environmental training is tightly linked to general training, then subsidies for the latter might significantly improve both productivity and environmental compliance. Targeted subsidies for environmental training could also improve compliance, but it is not clear whether large or small plants should be targeted. Our results suggest that large plants provide more environmental training, so subsidies for smaller facilities might have the greatest impact on compliance. However, subsidies could be more socially productive in large plants with greater emissions volumes and well-established programs for general training. Future research should address these issues, since environmental training appears to be an important determinant of compliance.

TABLE XII
Second-Stage Probit Results

Variable	COMPLY	COMPLY
EMS (IV)[a]	0.025	0.025
	(1.904)	(2.665)
LABOR (IV)	−0.921	−0.884
	(0.911)	(0.994)
MGT (IV)	8.034	8.015
	(2.715)	(2.974)
TRAINING (IV)	1.710	1.744
	(1.745)	(2.064)
METALS	−0.707	−0.550
	(2.272)	(2.373)
FOOD	−0.443	
	(1.534)	
CHEMICALS	−0.048	
	(0.169)	
SIZE	−0.006	
	(0.020)	
TECH	−0.035	
	(0.481)	
EMPSEC	0.005	
	(0.992)	
CONSTANT	−8.491	−8.633
	(2.696)	(3.081)
Pseudo-R^2	0.082	0.081
Chi-square	19.35	21.48
Prob > chi-sq.	0.0360	0.0007
Observations	170	191

[a] IV—instrumental variable

instrumented using the first-stage results. The probit equation is specified as follows (corresponding variables from Eq. (3b) are noted in parentheses)[16]:

$$\begin{aligned}\text{COMPLY} = f(&[\text{EMS, LABOR, MGT, TRAINING}](E),\\ &[\text{FOOD, CHEMICALS, METALS}](S),\\ &\mathit{SIZE}(Q), \mathit{TECH}(V), \mathit{EMPSEC}(N)),\end{aligned}$$

where COMPLY = 1 if self-assessed performance (Table III) is in categories 1 or 2; 0 otherwise.

The first column of Table XII presents full results, while the second presents results for the management variables after insignificant cost proxies have been dropped. For ease of interpretation, we have repeated the definitions of relevant variables.

[16] International management experience (X) was tested in initial runs, but was never found to be significant.

EMS—adoption score for EMS;

LABOR—significant assignment of workers to environmental work? (1 if yes);

MGT—environmental manager also assigned to other work? (1 if yes);

TRAINING—is environmental training given to nonenvironmental workers? (1 if yes);

FOOD, CHEMICALS, METALS—dummy variables for the Food, Chemicals, and Metals sectors;

SIZE—sequential categorical variable (1 if employment 16–100; 2 if 100–250; 3 if greater than 250);

TECH—proportion of equipment acquired since 1990;

EMPSEC—proportion of employees who have completed secondary education.

Surprisingly, our results suggest that LABOR (assignment of more workers to environmental monitoring and enforcement) has no significant effect. However, plants with higher EMS scores perform significantly better, even after simultaneity effects are purged.

Our results also suggest that mainstreaming works: The significant impacts for MGT and TRAINING suggest that more compliant plants assign environmental responsibility to general managers and provide environmental training to nonenvironmental workers as well as environmental specialists. Interpretation of this result depends on one's behavioral model. We believe that firms are experimenting with a variety of approaches because environmental management is a new field in Mexico. However, we recognize that some additional assumptions would make our results consistent with a model of profit-maximizing choice among well-known techniques. As we noted previously, environmental specialization in training and management may be cost-effective for plants whose environmental problems are technically complex, concentrated at a few points, and separated from standard production processes. If one assumes that abatement costs are significantly higher for such plants, then profit maximization dictates *both* more specialized management and lower average compliance rates. The result is a negative association between specialized management and compliance, but it has nothing to do with experimentation.

Are abatement costs really higher for such plants? A priori, it is possible to construct arguments for and against this proposition. We cannot test it with our data, and we are not aware of any empirical work on the issue.

Among the other variables in the complete compliance equation, only one sector dummy (METALS) has any significant effect. Once we control for management effort and degree of mainstreaming, we find that worker education, plant size, and technology vintage do not significantly affect compliance. Of course, size and education have indirect effects through their impacts on EMS and mainstreaming. However, technology vintage has no effect in either stage of the analysis. This runs strongly counter to the conventional wisdom, but the result seems reasonably robust. As Table XIII shows, our sample plants exhibit wide variation in the proportion of equipment installed since 1990. If there were a significant effect, we would expect to observe it in such a highly varied sample.

TABLE XIII
Proportion of Plant Installed Since 1990

	Frequency	%
0–20%	124	53.9
21–40%	33	14.4
41–60%	26	11.3
61–80%	13	5.6
81–100%	34	14.8

4.3. *Implications of the Results*

The results in Tables XI and XII can be combined to yield some tentative conclusions about the determinants of environmental compliance in Mexican industry. Through their impact on EMS (adoption of ISO 14001–type procedures), we find significant effects for plant size, multi-plant status, educated workers, and recent experience with regulation. A few of our exogenous variables also affect performance through their impact on mainstreaming. Plant size has countervailing effects in this context: It encourages generalized environmental training, but it also encourages specialized management. Experience of recent regulation has a perverse, albeit weak, effect on performance through encouragement of specialized management. Firms which are publicly traded, on the other hand, are significantly more likely to train nonenvironmental workers, with positive consequences for environmental compliance.

Among the significant variables, we are interested in identifying the most influential. To measure relative impacts, we predict levels of environmental management and compliance using low- and high-range values for the significant variables. Table XIV summarizes the values used for prediction.

Figure 2 presents results for the determinants of EMS, the environmental management index. On a scale of 0 to 100, we find that "worst-case" plants have a predicted index value of 14. Such plants are small, are not part of multiplant firms, have no employees with postsecondary education, and have experienced very weak regulation, if any. As we substitute high values of the exogenous variables, the score improves progressively: by 17 for strong regulation; by 22 for 100% postsecondary education; by 29 for large size; and by 16 for ownership by a multiplant firm. Plants with all the high-level characteristics have a predicted index value of 98: nearly complete implementation of an environmental management system. Although regulation clearly matters, our results suggest that a very large proportion of the difference between firms with weak and strong EMS implementation is explained by education, plant size, and multidivision status.

TABLE XIV
Simulation Values for Exogenous Variables

	SIZE	PUBLIC	EMPHIGH	MULTIDIV	RULES	METALS
Low	1	0	0	0	1	0
High	3	100	100	1	5	1

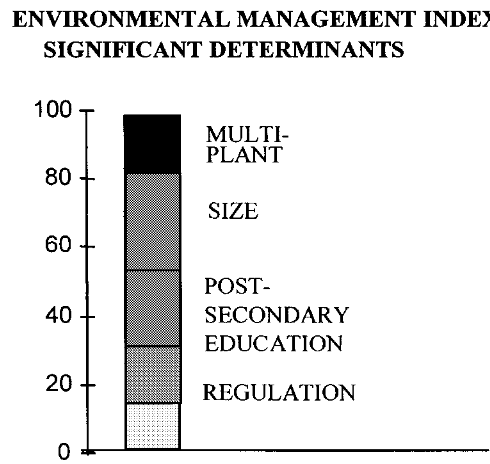

FIG. 2. Relative impact on environmental management.

The impacts of exogenous variables on EMS are of strong interest, because both our bivariate and multivariate results suggest that this variable is the most important determinant of compliance. However, a larger set of exogenous variables have an impact on compliance probability through the two training variables. Figure 3 summarizes the total impact of the exogenous variables on compliance. Within our sample, "worst-case" plants have a predicted compliance probability of about 12%, while "best-case" facilities have a 96% probability of compliance. Figure 3 illustrates the incremental contributions: Production in nonmetals sectors adds 12%; all shares publicly traded adds 6%; large size 13%; multiplant status 11%; postsecondary education 16%; and strong regulation 26%. For compliance, strong regulation emerges as the most important variable.

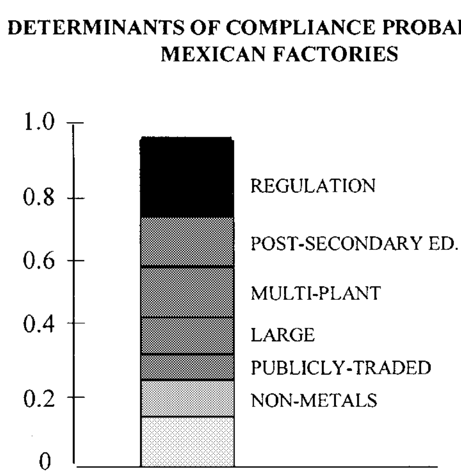

FIG. 3. Relative impact on compliance probability.

To summarize, our econometric analysis has narrowed a broad range of theoretically plausible determinants of compliance to a small, highly influential group. Comparison of Tables VI–X with Fig. 3 suggests both similarities and differences between the bivariate and multivariate results. The "structural" determinants of MAC (sector, size, multiplant status) are important in both. Among EMP determinants, the same is true for publicly traded status. However, the impacts of education and formal regulation emerge much more clearly in the multivariate analysis. Conversely, the apparent importance of some international links in the bivariate analysis (international management experience, OECD trade links) disappears in the multivariate analysis.

5. SUMMARY AND CONCLUSIONS

This paper uses new survey data to analyze the determinants of environmental compliance in Mexican factories. In our model, equilibrium emissions intensity (emissions/output) for cost-minimizing plants is determined at the point where marginal abatement cost (MAC) equals the expected marginal penalty (EMP). Plants whose equilibrium emissions intensities are significantly greater than the legal standard have a high probability of noncompliance. Because it includes extralegal determinants of environmental performance, our model also allows for the observable fact that plants are frequently cleaner than the law requires. Such plants have equilibrium emissions intensities significantly lower than the regulatory standard.

Theoretical determinants of MAC include variables related to plant size, multidivision status, sector, process vintage, human resources, and environmental management. Determinants of EMP include measures of formal regulation, informal regulation, ownership, and trade links. We estimate a reduced-form model, in which environmental compliance is used as a proxy for unobservable emissions intensity. Because environmental management variables are endogenous, we estimate the model in two stages. In the first stage, the four environmental management indices are regressed on the other determinants of MAC and EMP. In the second stage, we use the first-stage results to estimate the impact of the instrumented management indices on environmental compliance.

We believe that our results shed useful light on two important questions. First, what determines environmental compliance? The results of our two-stage estimation exercise are simple, clear, and relatively consistent. We can summarize our principal findings as follows:

1. Process is important: Plants which institute ISO 14001–type internal management procedures exhibit superior environmental compliance.

2. Mainstreaming works: Environmental training for all plant personnel is more effective than developing a cadre of environmental specialists; assigning environmental tasks to general managers is more effective than using special environmental managers.

3. Regulatory pressure works: Plants which have experienced regulatory inspections are significantly cleaner than their counterparts.

4. Public scrutiny promotes stronger environmental policies: Publicly traded Mexican firms are significantly cleaner than their privately held counterparts.

5. Size matters: Large plants in multiplant firms are much more likely to adopt policies which improve environmental performance.

6. OECD influences do not matter: Analyses of pollution control in developing countries generally assume that plants linked to the OECD economies have superior environmental performance. However, our multivariate analysis does not find a significant association for *any* OECD linkage: multinational ownership, trade, or international management experience.

7. New technology is not significantly cleaner in practice: We find no evidence that plants with newer equipment have better environmental performance, once other factors are accounted for.

8. Education promotes clean production: Plants with highly educated workers have significantly greater environmental management effort and compliance.

The second question relates to the design of environmental policy in developing countries. In our survey results, Mexican plants exhibit great variety in both level and type of environmental management effort. However, our results suggest that some approaches to environmental management are working much better than others. In our view, many of these differences exist because of incomplete information available to Mexican managers. If we are correct, then the government may improve compliance by promoting environmental management training for private firms.

More generally, our results suggest that conventional pollution control policy prescriptions may be too narrow for environmental agencies in developing countries. Of course, our results do not suggest that these prescriptions are wrong. The significance of the regulatory variables in our regressions underscores the importance of strengthened regulatory institutions. Stricter regulation raises the price of pollution and provides an important incentive for pollution reduction. However, our results also highlight the potential of programs which promote more effective environmental management and training within plants. Such programs can increase plants' responsiveness to the pollution control incentives provided by regulation and other determinants of MAC/EMP. In some cases, their impact may warrant the diversion of substantial resources from conventional regulation to environmental information and training programs.

APPENDIX 1: SAMPLE DISTRIBUTIONS OF MODEL VARIABLES

Ownership: Publicly Traded/Privately Held

	Number	%
Private	124	59.6
Mixed	14	6.7
Publicly traded	70	33.7

Ownership: Mexican/Multinational

	Number	%
Mexican	209	90.9
Multinational	21	9.1

Firm Type

	Number	%
Single plant	105	46.7
Multiplant	125	53.3

Reported Influence of Regulation

	Number	%
Low	35	14.8
Medium	37	15.7
High	164	69.5

Prior Experience of Inspection

	Number	%
No	38	16.7
Yes	189	83.3

Worker Education

% with secondary education	Number	%
0–25	71	33.2
26–50	74	34.6
51–75	26	12.1
76–100	43	20.1

Distribution of Shipments to OECD, Mexico, and Other

	Mean	SD	Max	Min
% of sales to OECD	14.0	25.2	100	0
% of sales to Mexico	80.8	29.3	100	0
% of sales to Other	5.2	12.5	100	0

Managers with Secondary Education as the Highest Level of Education

Highest Level of Education	Frequency	%
Secondary	4	1.7
Other	226	98.3

OECD Experience of Person in Charge

	Frequency	%
Without experience	172	72.6
With experience	65	27.4

APPENDIX 2: ISO 14001 STANDARDS FOR ENVIRONMENTAL MANAGEMENT[17]

Certification by the International Standards Organization (ISO) is considered important by many firms seeking rapid growth in the international marketplace. Many leading multinationals attach a strong preference to subcontractors which have satisfied ISO requirements, in particular the ISO 9000 series of quality control standards. Although only published in 1996, the ISO 14001 series of standards for Environmental Management Systems (EMS) has already attracted significant attention from industry.

Within the ISO 14001 series, some standards are still under negotiation. However, the EMS standard has been finalized, and requires organizations seeking certification to take the following steps:

1. An initial review by management to identify environmental issues of concern (e.g. excessive use of polluting inputs; the potential for a serious environmental accident);

2. Establishment of priorities for action, taking into account factors such as local environmental regulations and potential costs;

3. Establishment of an environmental policy statement, to be signed by the CEO, which includes commitments to compliance with environmental regulations, pollution prevention and continuous improvement;

4. Development of performance targets based on the policy statement (e.g. reduction of emissions by a set amount over a defined period);

5. Implementation of the EMS, with defined procedures and responsibilities;

6. Implementation reviews, performance measurement, and management audits.

Although new, ISO 14001 is already having a significant impact on the environmental stance of firms in both industrial and developing countries. In Europe, businesses are rapidly adopting an Eco-Management and Audit Regulation (EMAR) established by the European Union, which incorporates the ISO 14001 principles, plus requirements that firms comply with environmental legislation and publicly report their environmental performance. To remain competitive in Europe, many Japanese companies are aggressively pursuing ISO 14001 certification, and a number of US firms have followed suit.

ISO 14001 is also receiving significant attention in developing countries. Early in 1997, Altos Hornos de México was the first Mexican company to be certified to ISO 14001 for part of its operations. Since then, it has been followed by a number of major Mexican facilities, both domestic and foreign-owned. The interest in EMS has extended to Mexico's Environment Ministry (SEMARNAP), which has incorporated a voluntary EMS into its regulatory system. To promote adoption, SEMARNAP will establish a set of incentives such as accelerated depreciation on environmental equipment and eligibility for simplified licensing procedures. In

[17]Our thanks to Paul Martin for extensive comments on a previous draft of this appendix, and to Richard Wells of The Lexington Group for very useful discussion of ISO.

Asia, both Indonesia and Philippines intend to incorporate ISO 14001 elements into their new programs for public disclosure of firms' environmental performance.

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