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What Drives Voluntary Eco-Certification in Mexico?

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Abstract

Advocates claim that voluntary programs can help shore up poorly performing command-and-control environmental regulation in developing countries. Although literature on this issue is quite thin, research on voluntary environmental programs in industrialized countries suggests that they are often ineffective because they mainly attract relatively clean plants free-riding on prior pollution control investments. We use plant-level data on some 59,000 facilities to identify the drivers of participation in the ISO 14001 certification program in Mexico. We find that regulatory fines spur certification: on average, a fine roughly doubles the likelihood of certification for three years. Hence, the program attracts dirty firms and at least has the potential to improve environmental performance. We also find that plants that sold their goods in overseas markets, used imported inputs, were relatively large, and were in certain sectors and states were more likely to be certified.

Key Words: voluntary environmental regulation, duration analysis, Mexico

JEL Classification Numbers: Q56, Q58, O13, O54, C41

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1. Introduction

Many of the world's worst environmental problems are now found in developing countries, not industrialized ones. For example, the five cities with the most severe sulfur dioxide air pollution and those with the worst particulate air pollution are in Asia, Latin America, the Middle East (Baldasano et al. 2003). To address such problems, regulators in developing countries, like their counterparts in industrialized countries, have relied principally on emissions standards, technology standards, and other command-and-control policies. Unfortunately, these policies have not been particularly successful. The reasons are well known (Russell and Vaughan 2003; Eskeland and Jimenez 1992). Written regulations are often riddled with gaps and inconsistencies. Environmental regulatory agencies lack funding, expertise, and personnel. And perhaps most important, the political will to allocate scarce resources to environmental protection and to enforce environmental regulations is often limited.

Faced with these challenges, stakeholders in developing countries are increasingly experimenting with policies that do not depend directly on regulators to issue mandates, monitor compliance, and sanction violations. Instead, they provide incentives for voluntary emissions reductions, including positive publicity, pollution control subsidies, and regulatory relief. For example, in Colombia and Chile, dozens of high-profile voluntary agreements between environmental authorities and industry have been signed over the past 15 years (Blackman et al. 2009; Jiménez 2007). The hope is that policies like these will sidestep the institutional and political constraints that have undermined command-and-control policies (World Bank 2000).

Although increasingly common, we know little about voluntary initiatives in developing countries, including what drives participation and whether participation spurs improvements in

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environmental performance. Empirical studies—particularly rigorous ones—are rare. A recent review of the nascent literature on the topic found only a handful of published articles, most of which were qualitative case studies (Blackman, In Press).

The much larger literature on voluntary environmental initiatives in industrialized countries raises serious questions about whether participation actually generates environmental benefits. A particular concern involves one of the three main types of voluntary initiatives—programs administered by regulatory authorities or nongovernmental organizations that invite firms to meet established environmental performance criteria.¹ Research suggests that the environmental benefits of these programs are often undermined by selection effects—that is, by their tendency to mainly attract firms that are either already relatively clean or becoming cleaner for reasons unrelated to the program (Vidovic and Khanna 2007; Morgenstern and Pizer 2007). Such firms have clear incentives to join voluntary programs: the costs are relatively low because few additional pollution control investments are required to meet the program’s environmental performance criteria, and the benefits can be significant. Firms that join for these reasons are said to “free-ride” on unrelated investments in pollution control (e.g., Lyon and Maxwell 2008; Alberini and Segerson 2002).

Yet findings from studies of voluntary policies in industrialized countries may not generalize to developing countries. Clearly, the socioeconomic context in which voluntary policies are implemented are different in industrialized and developing countries. So too are the aims of these policies. In industrialized countries, voluntary policies are generally used to encourage firms to overcomply with mandatory regulations (Lyon and Maxwell 2002; Koehler 2008). In developing countries, by contrast, advocates hope they will help remedy rampant noncompliance with mandatory regulation (Blackman 2008). Given this role, the stakes for the success of voluntary regulation in developing countries are high.

This paper examines the drivers of Mexican participation in the International Organization for Standardization (ISO) 14001 program, the voluntary environmental program with the largest number of participating plants worldwide. We use a unique data set along with duration analysis to identify the drivers of participation in the program. We are particularly

¹ Prominent examples in the United States are the Environmental Protection Agency’s 33/50 and Climate Wise programs. The two other main types of voluntary regulation are agreements negotiated between regulatory authorities and firms, and unilateral commitments undertaken by firms (Lyon and Maxwell 2002).

interested in determining whether certified participants tend to be already clean plants free-riding on unrelated investments in pollution control.

Our results suggest that the program does appear to attract relatively dirty firms under pressure from regulatory authorities. Therefore, ISO 14001 certification at least has the potential to improve environmental performance. We also find that plants that sold their goods in overseas markets, used imported inputs, were relatively large, and were in certain sectors and states were more likely to be certified.

The remainder of the paper is organized as follows. Section 2 provides background on the ISO 14001 program. Section 3 briefly reviews the relevant literature. Section 4 discusses our data and variables. Section 5 presents our duration model. The last section sums up and discusses policy implications.

2. Background

ISO issued its 14001 series certification for environmental management systems (EMSs) in 1996 and revised it in 2004. As of December 2007, more than 150,000 facilities in 148 countries had been certified (ISO 2009). To obtain ISO 14001 certification, which is valid for three years, plants must meet five criteria that together constitute a “plan-do-check-act” cycle. They must

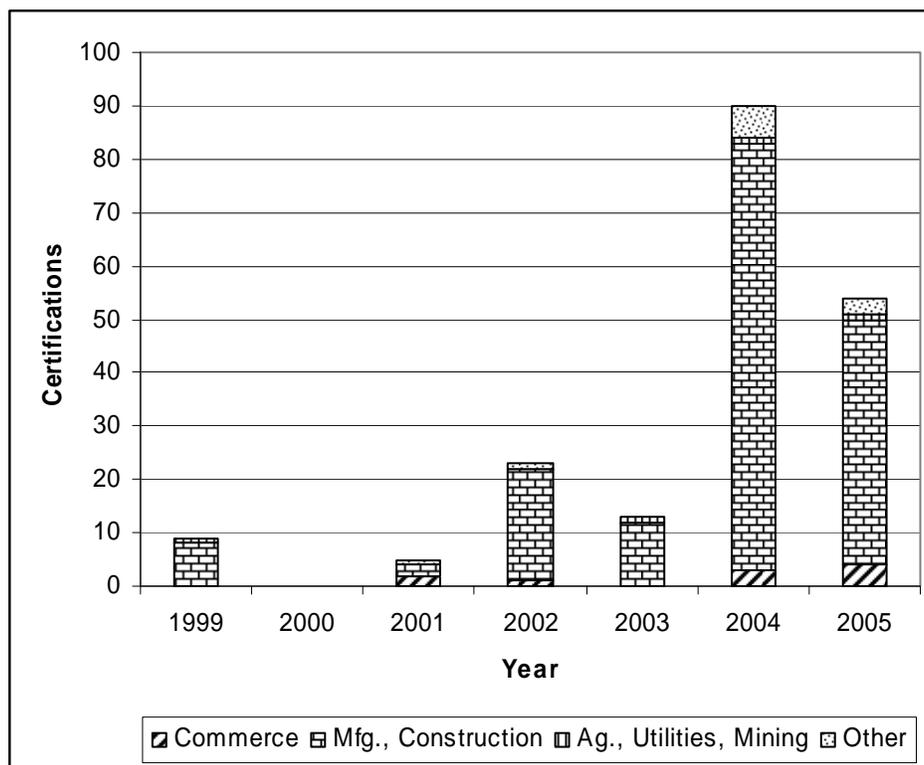
- define an environmental management strategy;
- make a concrete plan to implement it (plan);
- implement the policy and document the results (do);
- conduct periodic internal performance audits (check); and
- take corrective action to promote continual improvement (act).

An independent third-party auditor approved by ISO must verify that these criteria have been met. A supposed requirement for ISO 14001 certification is compliance with all applicable local environmental regulations. However, the stringency with which plants are held to this and other ISO 14001 criteria vary across countries and within them. Beyond regulatory compliance, plants need not meet hard performance targets to be certified: in general, certification requirements focus on procedures rather than outcomes. The cost of certification can be quite substantial. They include the costs of third-party audits, creating a new EMS or modifying an existing one, and continually implementing that EMS. In the United States, audit costs range

from \$239 to \$1,372 per employee, and implementation costs range from \$29 to \$88 per employees (Darnall and Edwards 2006).

ISO 14001 certification in Mexico grew from zero plants in 1998 to 525 by the end of 2005 (Contacto 2005). However, the majority of these 525 plants were state-owned electric generating units (owned by Comisión Federal Electricidad) and petroleum refineries and distribution terminals (owned by Petróleos Mexicanos). We do not include these plants in our analysis because our data on plant characteristics (described in Section 4.1) are restricted to private sector facilities. In addition, the drivers of ISO 14001 certification and environmental performance are likely different for publicly owned and privately owned plants. Figure 1 presents data on ISO 14001 certification by sector and year between 1999 and 2005 for the sample of 194 plants included in our empirical analysis.² It shows that the lion's share of certifications in this period were in the manufacturing sector and occurred in 2004 and 2005.

Figure 1. Within-Sample ISO 14001 Certification in Mexico, by Year and Sector (n=194)



² The selection of the sample is discussed in Section 3.1.

3. Literature

This section first reviews the literature on the drivers of voluntary environmental programs (VEPs) generally, and then summarizes research on ISO 14001 certification specifically.

3.1. *Voluntary Environmental Programs*

Empirical research on VEPs in industrialized countries suggests that pressures applied by regulators, markets, and civil society drive participation, as does variation in transaction costs associated with joining these programs (for reviews, see Lyon and Maxwell 2002; Alberini and Segerson 2002; and Khanna 2001).

A prominent theme in the literature is that firms participate in VEPs to preempt more stringent mandatory regulation or to soften enforcement of existing regulation (Segerson and Miceli 1998; Maxwell et al. 2000). Empirical evidence for this effect comes mostly from the 33/50 program of the U.S. Environmental Protection Agency (EPA).³ For example, Khanna and Damon (1999), Videras and Alberini (2000), Sam and Innes (2008), and Vidovic and Khanna (2007) all find that firms named as potentially responsible parties at a higher-than-average number of Superfund sites were more likely to join. Closely related to the hypothesis that regulatory pressure drives firms into voluntary programs is the notion that firms join to obtain preferential treatment from regulators. For example, Cothran (1993) and Decker (2003) find that firms obtain permits for new facilities more quickly if they have engaged in voluntary abatement.

Market incentives may also motivate VEP participation. Theory suggests that firms may voluntarily improve their environmental performance to attract “green” consumers (Arora and Gangopadhyay 1995), and some empirical evidence from VEPs supports this hypothesis. For example, Arora and Cason (1996) and Vidovic and Khanna (2007) show that firms with a higher ratio of advertising expenditures to sales were more likely to participate in EPA’s 33/50 program. Pressures generated by communities and nongovernmental organizations may also create incentives for firms to join voluntary programs. For example, Earnhart (2004) finds that average income and education in the local community—proxies for such pressures—help explain the environmental performance of municipal wastewater treatment facilities in Kansas.

³ Launched in 1991, the 33/50 program required participants to pledge to cut their emissions of 17 high-priority toxic chemicals by 33 percent by 1992 and by 50 percent by 1995.

The transaction costs associated with joining VEPs inevitably vary across firms because of, for example, differences in human capital. This variation helps explain participation (Delmas and Marcus 2004). For example, Blackman and Mazurek (2001) find that in a sample of 11 firms, transaction costs associated with participating in EPA's Project XL averaged more than \$450,000 per firm, varied considerably across firms, and deterred some firms from participating.

3.2. ISO 14001 Certification

Although several papers examine the drivers of ISO 14001 certification, only a handful test for the effects of past environmental performance and regulatory pressure. All focus on U.S. manufacturing facilities (but use different samples and measures of environmental performance). Most but not all of these studies find that dirtier plants are more likely to be ISO 14001 certified. Darnall (2003) finds that plants in violation of hazardous waste and atomic energy regulations are more likely to be certified. King et al. (2005) find that plants with toxic emissions higher than the average for their size and sector are more likely to be certified. And Potoski and Prakash (2005) find that plants with higher emissions of conventional air pollutants are more likely to be certified. Toffel (2007) reaches a different conclusion, however. He finds that although plants with higher absolute toxic emissions are more likely to be certified, the opposite is true of plants with higher emissions per unit of output. Finally, Potoski and Prakash (2005) find an inverted U relationship between compliance with Clean Air Act regulations and ISO certification: plants never in compliance and those always in compliance are more likely to be certified than those that are sometimes in compliance.

Although limited, the evidence on the effect of regulatory pressure on ISO certification consistently suggests a positive correlation. Using data on Japanese manufacturing plants, Arimura et al. (2005) find that plants subject to environmental performance standards and input taxes are more likely to be certified, and Potoski and Prakash (2005) find that plants inspected more often are more likely to be certified.

As for nonregulatory drivers of certification, virtually all econometric studies of ISO 14001 adoption test for the effect of firm size and conclude it is positively correlated with certification (Arimura et al. 2005; Christmann and Taylor 2001; King et al. 2005; Nakamura et al. 2001; Nishitani 2009; Potoski and Prakash 2005). Finally, most studies test for the effect of sales to foreign buyers and virtually all conclude it, too, is positively correlated with certification (Arimura et al 2005; Bansal and Hunter 2003; Christmann and Taylor 2001; King et al. 2005; Nishitani 2009).

4. Data and Variables

4.1. Data

Official Mexican plant-level census data are not available. We constructed a plant-level data set from four sources. The first is a list of all 525 Mexican facilities that obtained ISO 14001 certification through December 2005, along with the plant's location and the year (but not date) of certification. This list was compiled from an annual registry published by *Contacto* magazine.⁴

The second data source is the July 2004 System of Mexican Business Information (Sistema de Información Empresarial Mexicano, SIEM). The Mexican Ministry of Economics compiles and maintains SIEM and uses it to promote Mexican commerce. By law, all private sector Mexican plants are required to provide basic data to SIEM. The database is constantly updated to include new entrants and omit plants that have exited the market. It is not time specific—that is, it does not indicate when plants entered SIEM or whether their characteristics subsequently changed. SIEM contains basic information on more than half a million facilities throughout Mexico, more than three-quarters of which are small-scale retail operations. The data include geographic location, sector, gross sales, accounting capital, and whether the facility exports, imports, and is a government supplier. Our SIEM data contain 528,618 records. However, to limit our subsample of uncertified facilities to those types of plants that had a proven history of ISO 14001 certification, we dropped all plants in sectors (defined by North American Industrial Classification codes) that were not also represented in the ISO 14001 database. This step eliminated approximately 80 percent of the plants in the SIEM data.⁵

Our third data source is a 2009 registry of fines levied by the Federal Environmental Attorney General's Office (Procuraduría Federal de Protección al Ambiente, PROFEPA) within the Ministry of the Environment, which is responsible for monitoring and enforcement of most environmental regulations. This registry contains records of every PROFEPA fine between January 1992 and December 2009, including the amount and date of the fine. It has data on 44,008 plants.

⁴ Unlike lists of Mexican ISO 14001 plants available on internet sites, *Contacto* includes plant location data needed to merge our four data sets.

⁵ This adjustment changes the question addressed by our duration model from, “for all private sector Mexican plants, what plant characteristics drive ISO 14001 certification?” to, “for all private sector Mexican plants in sectors with at least one ISO 14001-certified plant, what plant characteristics drive certification?”

Our final source set is a 2007 list of 3,850 Mexican *maquiladoras* obtained from a commercial registry (Mexico's Maquila Online Directory 2007). Designed to take advantage of relatively inexpensive Mexican labor, *maquiladoras* are foreign-owned assembly plants that import inputs and export outputs without paying tariffs or duties.

We merged information on certification from the ISO 14001 database, plant characteristics from the SIEM and *maquila* databases, and fines from the PROFEPA database to create the plant-level data set used in the econometric analysis. Because the four databases do not have a common numerical code identifying individual plants, we merged them by nonnumerical identifiers—plant name, state, and *municipio* (county).⁶ These nonnumeric data did not uniquely identify plants. For example, in the SIEM data, multiple records have the same plant name, state, and *municipio*. To avoid incorrectly matching records, we dropped all records that were not uniquely identified. This resulted in a loss of 5 to 20 percent of the records in each data set. The end result was a sample of 59,149 plants, of which 194 were ISO 14001 certified and 58,955 were not.

4.2. Variables

This section discusses the independent variables used in the econometric model. We focus first on time-varying variables and then on the time-invariant variables.

4.2.1. Time-Varying Independent Variables: Fines

Of the potential drivers of ISO 14001 certification, we are particularly interested in the threat of regulatory sanctions. To proxy for this threat, we construct a set of dummy variables indicating how recently the plant has been fined. They are the only time-varying independent variables in our econometric model. We discuss how they enter into the model in Section 4.3, below. Here, we briefly present summary statistics on PROFEPA fines between 1992 and 2005 (Table 1). In our entire sample of 59,149 plants, 2 percent were fined. Of the 1,270 plants that were fined, the average number of fines was two per plant, and the average fine was 60,000 pesos (approximately US\$6,000).

⁶ Using finer geographical identifiers (e.g., city) proved to be impractical because of a lack of uniformity across the databases.

Table 1. PROFEPA Fines, 1992–2005

Sample → ↓		<i>All</i>	<i>ISO 14001 participants</i>	<i>ISO 14001 nonparticipants</i>
<i>All plants</i>	Fined	(n = 59,149) 2.15%	(n = 194) 35.05%	(n = 58,955) 2.04%
<i>Fined plants</i>	Total fines	(n = 1,270) 2,511	(n = 68) 141	(n = 1,202) 2,370
	Average fines/plant	1.98	2.07	1.97
	Average fine (pesos)	60,142.58	89,868.47	58,460.91

Table 1 shows that ISO 14001-certified plants were fined far more often than uncertified plants: 35 percent of certified plants were fined versus only 2 percent for uncertified plants. Hence, there appears to be a simple correlation between fines and ISO 14001 certification. However, this correlation does not necessarily imply causation, for at least two reasons. First, it may have been generated by underlying differences in plant characteristics. For example, it could simply reflect a tendency for large plants to be fined and also to obtain ISO 14001 certification. Second, it does not take into account the intertemporal relationship between these events. For example, it lumps together cases in which a fine was followed by certification 1 year later and cases in which a fine was followed by certification 10 years later, even though the former are more likely to represent actual causation. Our econometric model addresses both of these issues: it controls for a variety of underlying plant characteristics and takes into account the intertemporal relationship between fines and certification.

4.2.2. Time-Invariant Independent Variables

Table 2 lists the time-invariant independent variables in the econometric model and presents sample means for the entire sample, the subsample of certified plants, and the subsample of uncertified plants.

Table 2. Time-Invariant Independent Variables and Sample Means

Variable	Explanation (all are 0/1 dummy variables)	All (n = 59,149)	ISO 14001 participants (n = 194)	ISO 14001 nonparticipants (n = 58,955)
EXPORT	exporter	0.1010	0.7320	0.0989
IMPORT	importer	0.1328	0.8041	0.1306
GSUPPLIER	government supplier	0.0820	0.1600	0.0818
MAQUILA	maquiladora	0.0098	0.3351	0.0087
SA_0_3M	gross revenue 0–3 million pesos	0.8571	0.1959	0.8593
SA_3M_12M	gross revenue 3–12 million pesos	0.0681	0.0825	0.0681
SA_12M_PLUS	gross revenue 12 million pesos +	0.0748	0.7216	0.0726
CAP_0_900	accounting capital 0–900K pesos	0.8200	0.2320	0.8220
CAP_901_5M	acc. capital 900K–5 million pesos	0.0850	0.0670	0.0851
CAP_5M_PLUS	acc. capital 5 million pesos plus	0.0949	0.7010	0.0929
SECTORD2	commercial wholesale	0.1117	0.0412	0.1119
SECTORD3	commercial retail	0.2018	0.0103	0.2024
SECTORD6	industrial manufacturing	0.1922	0.8660	0.1899
SECTORD7	information, mass media	0.1256	0.0103	0.1260
SECTORD8	mining	0.0010	0.0206	0.0009
SECTORD9	other services not gov't activities	0.0071	0.0103	0.0071
SECTORD15	real estate services	0.1115	0.0103	0.1118
SECTORD16	professional, scientific, technical	0.1552	0.0103	0.1557
SECTORD17	transport, mail, services	0.0314	0.0103	0.0315
STATE_AGU	Aguascalientes	0.0107	0.0361	0.0107
STATE_BCA	Baja California	0.0250	0.1392	0.0247
STATE_CHI	Chihuahua	0.0403	0.1082	0.0401
STATE_COA	Coahuila	0.0226	0.0722	0.0225
STATE_COL	Colima	0.0030	0.0052	0.0030
STATE_DIF	Distrito Federal	0.2561	0.0670	0.2567
STATE_GTO	Guanajuato	0.0397	0.0309	0.0398
STATE_HID	Hidalgo	0.0395	0.0052	0.0396
STATE_JAL	Jalisco	0.1496	0.0258	0.1500
STATE_MEX	Mexico State	0.1009	0.1598	0.1007
STATE_NUL	Nuevo Leon	0.0733	0.0773	0.0733
STATE_OAX	Oaxaca	0.0047	0.0052	0.0047
STATE_PUE	Puebla	0.0227	0.0464	0.0226
STATE_QUE	Querétaro	0.0108	0.0515	0.0106
STATE_SLP	San Luis Potosi	0.0069	0.0103	0.0069
STATE_SIN	Sinaloa	0.0122	0.0103	0.0122
STATE_SON	Sonora	0.0135	0.0052	0.0135
STATE_TAM	Tamulipas	0.0154	0.0876	0.0152
STATE_TLA	Tlaxcala	0.0052	0.0155	0.0052
STATE_YUC	Yucatán	0.0200	0.0103	0.0198
STATE_ZAC	Zacatecas	0.0030	0.0052	0.0030

EXPORT is a dummy variables identifying plants that export at least some of their products. We expect EXPORT to be positively correlated with the probability of certification. Almost 90 percent of Mexican exports are sold in the United States (Clifford 2001). U.S. consumers, including buyers of intermediate products, may be more concerned about the environmental performance of Mexican firms than are domestic consumers.

IMPORT is a dummy variable identifying plants that export at least some of their products. We expect IMPORT to be positively correlated with certification because plants that import may be better integrated into the global economy and therefore may have better access to pollution prevention and control technology.

MAQUILA is a dummy variable identifying *maquiladoras*. Of the sample plants, 1 percent are *maquiladoras*. We expect MAQUILA to be positively correlated with certification for the same reason that we expect EXPORT and IMPORT to be positively correlated, and because *maquiladoras* are often required to meet company-wide international standards for environmental performance (Garcia-Johnson 2000; Hutson 2001).

GSUPPLIER is a dummy variable identifying plants that sell their products to the Mexican government. We expect GSUPPLIER to be positively correlated with the probability of certification because government entities that purchase products from private sector suppliers may have bureaucratic incentives to favor suppliers that are ISO 14001 certified.

Two sets of dummy variables—on sales and capitalization—measure plant size. SA_0_3M is a dummy variable indicating that the gross revenue of the plant falls between zero and 3 million pesos (approximately US\$300,000). The other two sales dummies have a similar interpretation. CAP_0_900K is a dummy variable indicating that the capitalization of the plant falls between zero and 900,000 pesos (approximately US\$90,000). The other two capitalization dummies have a similar interpretation.⁷ Empirical research suggests that large plants are typically more likely to participate in voluntary regulatory programs (Lyon and Maxwell 2002; Kohler 2008). Participation inevitably involves fixed transaction costs that arise from, among other things, meeting new bureaucratic requirements. These fixed costs generate economies of scale (Blackman and Mazurek 2001).

⁷ The SIEM data do not include the actual values of sales or capital for each plant, only ranges of these variables into which the actual values fall.

Nine dichotomous dummy variables identify the plants' economic activity. These sector fixed effects are drawn from the 17 sector categories in the SIEM dataset. Our ISO 14001 data set of 194 plants had no private sector plants in six of these categories. Therefore, as discussed in Section 4.1, we dropped all observations in these six sectors from our data set, effectively eliminating the corresponding sector dummies from the regression model.⁸ In addition, to make the model estimable, we dropped two additional sector dummies that were nearly perfectly correlated with the dependent variable—that is, dummies for which only one plant in our data set was ISO certified.⁹ The three sectors with the greatest number of sample plants in the entire merged data set are commercial retail (SECTOR3, 20 percent), industrial manufacturing (SECTOR6, 19 percent), and professional-scientific-technical (SECTOR16, 16 percent), which together constitute 55 percent of the sample. Presumably, plants in some sectors have stronger incentives to obtain ISO 14001 certification than others. These may be sectors that are particularly dirty and sell to consumers who are particularly concerned about environmental performance.

Finally, 21 location fixed effects dummy variables identify the state where each plant is located. To make the model estimable, starting with 31 states plus the Federal District, we dropped 11 state dummies that were perfectly correlated with the dependent variable—that is, dummies for states in which no plants in our merged data set were ISO 14001 certified between 1999 and 2005.¹⁰ Presumably, plants in some locations have stronger incentives to obtain ISO 14001 certification than others. For example, these may be locations where consumers are particularly concerned about environmental performance.

5. Econometric Model

This section discusses the empirical strategy for our participation model, explains how fines enter into the model, and presents our results.

⁸ Specifically, we dropped plants in Sector 1 (agriculture, livestock, forestry, fishing, and hunting), Sector 5 (electricity, water, and gas), Sector 11 (waste management, remediation), Sector 12 (entertainment, culture, and sports), Sector 13 (health and social assistance), and Sector 14 (educational services).

⁹ Specifically, we dropped plants in Sector 4 (construction) and Sector 10 (temporary lodging, food and beverage preparation).

¹⁰ Specifically, we dropped dummies for Baja California Sur, Campeche, Chiapas, Durango, Guerrero, Michoacán, Morelos, Nayarit, Quintana Roo, Tabasco, and Veracruz.

5.1. Empirical Strategy: Duration Analysis

We use a duration model to analyze ISO 14001 certification. Such models are used to explain intertemporal phenomena, such as the length of time that patients with a life-threatening disease survive, and the length of time that industrial facilities operate before adopting a new technology.¹¹ Duration models estimate a hazard rate, h , which may be interpreted as the conditional probability that a phenomenon occurs at time t given that it has not already occurred and given the characteristics of the unit of analysis (patient, plant) at time t . The hazard rate is defined as

$$h(t, \mathbf{X}_t, \boldsymbol{\beta}) = f(t, \mathbf{X}_t, \boldsymbol{\beta}) / (1 - F(t, \mathbf{X}_t, \boldsymbol{\beta})) \quad (1)$$

where $F(t, \mathbf{X}_t, \boldsymbol{\beta})$ is a cumulative distribution function that gives the probability that the phenomenon (death, adoption of a technology) has occurred prior to time t , $f(t, \mathbf{X}_t, \boldsymbol{\beta})$ is its density function, \mathbf{X}_t is a vector of explanatory variables related to the characteristics of the unit of analysis (which may change over time), and $\boldsymbol{\beta}$ is a vector of parameters to be estimated. In this paper, to analyze ISO 14001 certification, the hazard rate is the conditional probability that a plant in our data set obtains certification at time t , given that it has not already been certified and given the characteristics of the plant at time t .

In duration models, the hazard rate is typically broken down into two components. The first is a baseline hazard, $h_0(t)$, that is a function solely of time (not of any explanatory variables) and that is assumed to be constant across all plants. The baseline hazard captures any effects not captured by explanatory variables, such as the diffusion of knowledge about ISO 14001 certification or changes in macroeconomic conditions. The second component of the hazard rate is a function of the explanatory variables. Combining these two components, the hazard rate $h(t)$ is written

$$h(t) = h_0(t) \exp(\mathbf{X}_t' \boldsymbol{\beta}). \quad (2)$$

¹¹ For an introduction, see Kiefer (1988).

The vector of parameters, β , is estimated using maximum likelihood.

A duration framework is appropriate for analyzing the effect of fines on ISO 14001 certification for two reasons. First, it explicitly accounts for the intertemporal relationship between these phenomena, which (as discussed above) helps determine whether fines actually cause certification. Second, it avoids the problem of right censoring that would arise in a cross-sectional probit or logit model if some plants that were not certified in December 2005 (when our panel ends) subsequently joined the program. A duration model circumvents this problem by estimating the conditional probability of certification in each period.

We use a Cox (1975) proportional hazard model. There are two broad approaches to specifying duration models. One is to make parametric assumptions about the time-dependence of the probability density function, $f(t, \mathbf{X}_t, \beta)$. Common assumptions include exponential, Weibull, and log-logistic distributions. Each assumption implies a different shape for the baseline hazard function, $h_0(t)$.¹² A second general approach is to use a Cox (1975) proportional hazard model, which does not require a parametric assumption about the density function. This feature accounts for the popularity of the Cox model among economists, and it is the reason we choose it. We use years as our temporal unit of analysis. Although we know the day on which plants were fined, we know only the year in which plants were ISO 14001 certified.¹³

Finally, note that although plants can and do obtain ISO 14001 certification more than once, our duration model seeks to explain the decision to obtain certification for the first time. As is standard practice with duration models, observations (here, plants) are dropped from the regression sample after their first “failure” (here, certification).

¹² For example, an exponential probability density function generates a flat hazard function, $h_0(t)$. The implication is that the probability of obtaining ISO 14001 certification (apart from the influences of regulatory activity and plant characteristics) stays the same over time. A log-logistic probability density function, on the other hand, generates a hazard function that rises and then falls.

¹³ As a result, in some years multiple plants are certified in the same year. Such “ties” create a complication because estimating the duration model requires identifying the number of plants still at risk of being certified each time a plant joins. If more than one plant is certified in the same period, the size of the risk pool in each period is not clear. We use the Breslow (1974) method for ties. In addition, our use of years as a temporal unit of analysis raises questions about whether time aggregation bias is a problem and whether a discrete-time representation might be more appropriate. In general, however, time aggregation bias is a problem only when hazard rates are high and/or the periods of measurement are long—that is, when a large number of failure events in a given interval begins eroding the underlying population of units at risk of failure (Petersen 1991). This is not the case in our sample: the number of plants obtaining certification in any given year is always quite small relative to the number of uncertified plants.

5.2. Modeling Fines

We include four fines variables in the duration model. FINE_1YR is a dichotomous dummy variable that identifies plants fined in the year prior to the current year, FINE_2YR is a dummy variable that identifies plants fined in the year two years prior to the current year, and FINE_3YR is a dummy variable that identifies plants fined in the year three years prior to the current year. Finally, FINE_3YR_PLUS is a dummy that identifies plants fined more than three years prior to the current year. We do not include a fine dummy variable for the current year to avoid conflating cases where a fine precedes ISO certification with cases where it follows certification.

5.3. Results

We discuss results for the time-varying and time-invariant independent variables separately.

5.3.1. Time-Varying Independent Variable: Fines

Table 3 presents regression results for the Cox proportional hazard model. Because the hazard function given by equation (2) is nonlinear, the estimated coefficients do not have a simple interpretation (technically, they can be interpreted as the effect on the log hazard rate of a unit change in the explanatory variable at time t). Exponentiated coefficients, however, can be interpreted as the hazard ratio—that is, the ratio of the hazard rate given an increase in an explanatory variable at time t (a unit increase in a continuous variable or a change from 0 to 1 of a dichotomous dummy variable) relative to the baseline hazard rate at time t . A hazard ratio greater than unity indicates that an increase in the explanatory variable increases the hazard rate relative to the baseline. For example, a hazard ratio of 2 means that an increase in the explanatory variable doubles the hazard rate relative to the baseline.

Table 3. Regression Results for Cox Proportional Hazard Model

(dependent variable = 0/1 indicator of ISO 14001 certification
in year T; T = 1992–2005; n = 59,149)

Variable	Haz. Ratio	S.E.	Variable	Haz. Ratio	S.E.
FINE_1YR	1.8256**	0.4876	STATE_AGU	3.0676*	1.8298
FINE_2YR	1.8272**	0.4730	STATE_BCA	2.2146	1.1316
FINE_3YR	2.0036***	0.4996	STATE_CHI	2.0948	1.0820
FINE_3YR_PLUS	1.0836	0.2581	STATE_COA	3.1594**	1.7077
EXPORT	1.5670*	0.4017	STATE_COL	4.9380	5.4358
IMPORT	2.5797***	0.7489	STATE_DIF	0.8276	0.4452
GSUPPLIER	1.2533	0.2763	STATE_GTO	1.5626	0.9535
MAQUILA	2.9469***	0.6204	STATE_HID	1.5884	1.7612
SA_3M_12M	1.3100	0.4346	STATE_JAL	0.4997	0.3177
SA_12M_PLUS	2.7892***	0.7805	STATE_MEX	3.5152***	1.7260
CAP_901K_5M	0.8776	0.2970	STATE_NUL	2.4173*	1.2729
CAP_5M_PLUS	2.6005***	0.6488	STATE_OAX	6.2543*	6.8611
SECTOR2	0.9381	0.7506	STATE_PUE	4.1103***	2.3211
SECTOR3	0.2252	0.2264	STATE_QUE	3.4652**	1.9319
SECTOR6	3.5425*	2.6116	STATE_SLP	3.1736	2.6735
SECTOR7	0.4033	0.4059	STATE_SIN	3.6474	3.0632
SECTOR8	11.3394***	10.2999	STATE_SON	0.9001	0.9914
SECTOR9	4.5858	4.6407	STATE_TAM	4.6169***	2.4390
SECTOR15	0.3655	0.3676	STATE_TLA	3.4312*	2.5567
SECTOR16	0.3792	0.3843	STATE_YUC	2.3088	1.9429
SECTOR17	0.8550	0.8697	STATE_ZAC	7.1669*	7.8722
Log Likelihood	-1621.2422				

***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Three of our four fine variables—FINE_1YR, FINE_2YR, and FINE_3YR—are significant at the 5 percent or 1 percent level, and one—FINE_3YR_PLUS—is not significant. The hazard ratios for FINE_1Y, FINE_2YR, and FINE_3YR indicate that a fine assessed one or two years before the current year increases the probability that a plant will obtain ISO 14001 certification in the current period by a factor of 1.8, and a fine assessed three years before the current year increases this probability by a factor of 2.0. The lack of significance of FINE_3YR_PLUS indicates that a fine assessed more than three years prior to the current period does not affect the probability of certification.

A potential concern about our analysis is that the FINE variables could, in principle, be endogenous if they are correlated with unobserved plant characteristics that affect certification.¹⁴ Although such endogeneity cannot be ruled out, it is unlikely to be driving the observed correlation between fines and certification. The reason is that endogeneity would be unlikely to generate the intertemporal response function implied by the results for our FINE variables—namely, an effect of fines on the probability of certification that diminishes the more distant in time was the fine. Instead, endogeneity would generate a response that did not change over time.¹⁵ Hence, our results suggest a causal relationship between fines and ISO 14001 certification.

5.3.2. Time-Invariant Independent Variables

The hazard ratios for EXPORT, IMPORT, and MAQUILA are greater than unity and significant at the 10 percent, 1 percent, and 1 percent levels, respectively. They indicate that plants selling their goods in overseas markets were 1.6 times more likely to obtain ISO certification, those that import foreign inputs were 2.6 times more likely, and those that were *maquiladoras* were 2.9 times more likely, all other things equal. The hazard ratio for GSUPPLIER is not significant.

Estimated hazard ratios for the sales and capital dummies suggest that larger plants were more likely to join the program. The reference groups for these dummies are plants with less than 3 million pesos in sales and those with less than 900,000 pesos in capital. The hazard ratio for SA_12MPLUS is significant at the 1 percent level, indicating that plants with more than 12 million pesos in sales were 2.8 times more likely to be certified than those in the reference group,

¹⁴ For example, aside from our sector dummies, our covariates do not include a precise measure of the complexity of the production process, so complexity is partly unobserved. It could be that complex plants are more likely to be fined because they have a higher potential for violating environmental regulations and are also more likely to obtain ISO 14001 certification because they tend to employ educated and sophisticated managers. If this were actually true, then fines would be endogenous.

¹⁵ Intraclass correlation is a second potential concern. Some plants in our regression sample are owned by the same firm. Presumably, in some cases, the decision to become ISO 14001 certified is made at the firm level. But in other cases, it is clearly made at the plant level—some plants owned by the same firm do not make the same certification decision. In cases where the certification decision is made at the firm level, our data may exhibit intraclass correlation. Ideally, we would correct for this correlation using clustered standard errors. However, we are not able to do that for two reasons. First, we cannot reliably identify cases where the certification decision is made at the firm versus the plant level. Second, our indicator of common ownership is unreliable. The only data we can use to determine whether plants share a common owner is their names. But in some cases, plants with different names are owned by the same parent firm.

all other things equal, and the hazard ratio for CAP_5M_PLUS is significant at the 1 percent level, indicating that plants with more than 5 million pesos in capital were 2.6 times more likely to be certified, all other things equal. These results comport with previous studies of voluntary programs that generally find larger facilities are more likely to participate.

For the sector fixed effects, the reference group comprises plants in the 2 sectors (among the 10 represented in our regression data) in which ISO certification is limited: Sector 4 (construction) and Sector 10 (temporary lodging, food and beverage preparation). Our regression results indicate that, compared with plants in these sectors, those in Sector 6 (industrial manufacturing) were 3.5 times more likely to be certified, and those in Sector 8 (mining) were 11.3 times more likely, all other things equal.

For the state fixed effects, the reference group comprises plants in 11 states in which ISO certification is limited: Baja California Sur, Campeche, Chiapas, Durango, Guerrero, Michoacán, Morelos, Nayarit, Quintana Roo, Tabasco, and Veracruz. Our regression results indicate that, compared with plants in these states, those in Aguascalientes, Coahuila, Mexico State, Nuevo León, Oaxaca, Puebla, Querátaro, Tamaulipas, and Zacatecas were more likely to be certified. Hazard ratios for Oaxaca, Tamaulipas, and Zacatecas are particularly large.

6. Conclusion

We have used data on some 59,000 industrial facilities and other business in Mexico to identify the drivers of participation in the ISO 14001 certification program for EMSs. We have used duration analysis because it explicitly accounts for the timing of the dependent variable (certification) and the main independent variable of interest (regulatory fines) and because it controls for right censoring. Our results indicate that fines motivate participation in the program. The magnitude of the effect is economically significant: on average, a fine roughly doubles the likelihood of joining the program for three years. We also find that, all other things equal, plants are more likely to participate if they sell their goods in overseas markets, use imported inputs, are *maquiladoras*, are large (as measured by gross revenues or capitalization), and are in certain sectors and states.

Our results suggest that the ISO 14001 program in Mexico does not simply comprise already-clean firms. Rather, it has attracted a significant number of dirty firms under pressure from regulatory authorities. Although one would hope that these firms subsequently improved their environmental performance, that conclusion does not necessarily follow—even if average performance of certified plants is superior to that of uncertified plants. It could be that some of

the dirty plants that were certified would have improved their environmental performance absent certification. Hence, by demonstrating that fines motivate dirty firms to obtain ISO 14001 certification, our analysis establishes a necessary, but not sufficient, condition for the program's generating environmental benefits. Further research on plants' postparticipation environmental performance is required to determine whether ISO certification actually has environmental benefits.

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