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The Impact of Operational Characteristics on Firms' EMS Decisions: Strategic Adoption of ISO 14001 Certifications

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ABSTRACT
Firms choose to seek environmental management system (EMS) certifications such as ISO 14001 for a variety of reasons. In this paper we put forward a hypothesis that firms seek ISO 14001 certifications for their establishments when their operations involve low degrees of complexity. Another hypothesis we consider is that firms facing more uncertainty in their operations (and hence more risk) seek ISO 14001 certifications. These hypotheses have not been yet addressed in the literature and are of particular interest to business managers and policymakers.

We empirically test these hypotheses using probit and duration models using matched establishment–firm–industry data for large Japanese manufacturers. Our findings support the first as well as the second hypotheses. This suggests that firms tend to certify more routine and less complex operations first, and that firms use ISO 14001 certifications as an insurance scheme. Copyright © 2009 John Wiley & Sons, Ltd and ERP Environment.

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Introduction

Environmental concerns continue to play an important role in firms' management decisions. Many firms decide to adopt some form of environmental management system (EMS) to address such concerns. Furthermore, some firms choose to be certified under recognized international standards. For example, ISO 14001 is an international, voluntary standard certification scheme for an EMS managed by the International Organization for Standardization (ISO), an international standard-setting body. In general, firms are not legally required to obtain ISO 14001 or any other types of environmental certification from ISO or other EMS certifying organizations. It is then of both academic and practical interest to study why firms choose to certify themselves under voluntary EMS certification schemes.[1]

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[1] Substantial studies exist in the literature on the determinants of firms' decisions to participate in various voluntary programs (e.g. Arora and Cason, 1995, 1996; DeCanio and Watkins, 1998).

A number of previous studies have addressed this question. The findings of these studies suggest that, broadly speaking, there are at least two types of circumstance, one external and the other internal, in which firms are likely motivated to seek EMS certifications (Rivera-Camino, 2001).[2] These types of circumstance are explained as follows.

The first type of circumstance is characterized by the presence of external pressures being placed on firms, where such pressures come from bodies that are external to the firms such as governmental agencies and markets in which the firms operate (Khanna and Anton, 2002). For example, strict government regulations on firms' environmental performance might motivate the firms to seek third-party EMS certifications with a serious intention for improving their environmental performance. Market considerations might also cause firms to feel pressured to seek certification. Another example concerns green consumerism. Many firms selling their products and services to consumers must often take into account the presence of green consumers, who prefer buying products produced by environmentally friendly production methods. Firms that sell their products in global markets must also know which country markets, for example, prefer or even require firms to provide such green products. Meeting the challenges brought about by green consumerism is also becoming an important aspect of firms' investor relationships. In order to signal their competence in maintaining environmentally friendly operations to consumers, firms often resort to certifications by a number of alternative environmental management systems. Alternatively, firms might wish to signal their environmental friendliness to their potential investors who want to buy (green) mutual funds focusing on investing in environmentally friendly corporations (e.g. Statman, 2000; Bauer *et al*., 2005).

The second type of circumstance in which firms are motivated to certify themselves arises when the firms face significant internal pressures, for example to improve their profitability by utilizing more fully their human resources and other internal resources. Such internal pressures might also be created when the executives of a firm champion the environmental cause in order to exercise their leadership. Some firms' management may choose to use improving their firms' environmental performance voluntarily as a convenient tool for creating a disturbance needed to restructure and improve profitability.[3]

Many factors that might cause these two types of circumstance may interact with each other and promote firms' decisions to obtain environmental certifications. For example, strict government regulations may not be enough for firms to adopt EMS certifications unless the firms have environmentally conscious managers and human resources. In such circumstances some managers may find the environment a good tool to take advantage of to promote themselves within the firm hierarchy. The relatively high cost of implementing and maintaining ISO 14001 may be another factor in this decisionmaking.[4]

In this paper we consider another type of circumstance in which firms might be motivated to certify. These circumstances are characterized by firms' considerations of operational aspects of their products. These operational reasons as firms' motivations for adoptions of EMS certifications are of strategic importance but have not yet been analyzed in the literature. Both practitioners and policymakers have interest in knowing what types of circumstance are compatible with EMSs because implementing an EMS represents a major investment decision for firms and a potential policy instrument for governments.

Operational Characteristics of Firms and EMS Certifications

ISO 14001 was published by the International Organization for Standardization in 1996. ISO 14001 certifies the environmental soundness of the process of firms' operations but does not warrant the environmental friendliness of the firms' output, or the general environmental performance of firms' operations. In this paper we use

[2] See, for example, Alemagi *et al.* (2006), Halila (2007), King and Lenox (2001), Nakamura *et al.* (2001) and National Database on Environmental Management Systems (2003).
[3] These two types of circumstance are often cited by firms as the reasons for their adoptions of EMS certifications. See National Database on Environmental Management Systems (2003, pp. 93–97) for an extensive literature survey on this topic.
[4] It is estimated that, for Japanese firms with revenues of 2–3 billion yen (approximately $20 million) and a few hundred employees, the average cost of ISO 14001 certification is 20–30 million yen (approximately $200,000) and the annual cost of maintaining ISO 14001 certification is close to 10 million yen (approximately $90,000). Also, the implementation costs and annual maintenance fees are 1.25 and 1.05 million yen for KES and 1.25 and 1.05 million yen (approximately $10,000 and $9,000) for EA21 (Takeishi, 2002; Hibiki and Arimura, 2005).

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ISO 14001 as our measure of EMS certifications by firms. While ISO 14001 is by no means the only indicator of EMS certification, it is the most representative one in the world.

Because ISO 14001 certifications are establishment-specific and voluntary, firms do behave strategically concerning them. More specifically, firms develop their own priorities and typically decide to obtain ISO 14001 certifications for some but not all plants (establishments).[5] In fact, few firms choose to seek certifications for all of their establishments under ISO 14001, and, where they do, the order with which their establishments are certified is usually dictated by the firms' strategic management priorities. There is a limited amount of anecdotal evidence suggesting that firms systematically choose to certify certain types of operation and not others.

For example, some Japanese firms' managers claim that ISO 14001 does not function well when a company introduces a new production system or adopts a fast-paced corporate management system (Nikkei Ecology, 2003). Canon Corporation found an EMS unfit for the innovative cell-production system introduced in one of its factories. The firm found that an EMS could not cope well with the types of trial and error process that occur frequently in such cell production environments. In its initial stage of implementation of an EMS, Sony aimed to institute the EMS only at the plant level, not at the corporate level, because the corporate structural changes were too frequent to accommodate possible corresponding changes of the EMS.[6] Different anecdotal evidence of inappropriateness of formal EMSs in certain situations concerns firms' innovation activities.

An environmental manager of a chemical product company claims that developing a new product utilizing recycled content requires a task-force team that is separated from the EMS because it needs concentrated efforts by specialists. Another environmental manager of an electronic company says that, while the R&D department carries out technological development related to environmental protection, the EMS has its role in standardizing the developed technology and that R&D and the EMS have different tasks (Takahashi and Nakamura, 2005).

These anecdotes suggest that firms do not choose to certify their operations under ISO 14001 (or other methods of EMS) if such operations contain significant complex characteristics. On the other hand, it is not unusual for firms to spend significant amounts of resources to make sure that their potentially environment-polluting operations with much uncertainty are properly managed for the environmental management point of view on a continuing basis. This is because many manufacturers face the potential (liability) risks of causing costly environmental problems themselves or in their suppliers' operations.[7]

In this paper we first present our hypotheses on firms' adoptions of ISO 14001 certifications based on the operational characteristics of the sorts discussed above. These hypotheses state that firms choose to certify operations under ISO 14001 if such operations contain significant amounts of simple or uncertain characteristics.[8] Using a newly created database we test these hypotheses while exploring empirically the determinants of Japanese manufacturing firms' decisions to adopt ISO 14001 certifications. Japanese firms are interesting to study, in part because they have obtained a very large number of ISO 14001 certifications (Table 1).

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
No. of acquisitions per year	106	383	727	1110	1693	2546	2705	2519	3198	2537	1903	987	364
No. of acquisitions (cumulative)	106	489	1216	2326	4019	6565	9270	11789	14987	17524	19427	20413	20777

Table 1. Acquisitions of ISO 14001 certification in Japan
Source: Japan Accreditation Board for Conformity Assessment (2009).

[5] We use 'plants' and 'establishments' interchangeably.

[6] Sony subsequently expanded its coverage of EMS certifications to all of its manufacturing establishments as well as non-manufacturing establishments with at least 100 employees. By 2005 Sony had all of these establishments ISO 14001 certified (Sony, 2006). Canon (2006) also introduced its plans to ISO 14001 certify many of its manufacturing as well as marketing establishments by 2007.

[7] In order to manage the environmental integrity throughout its supply chain, Sony has a policy to procure only from its green partners who satisfy certain levels of environmental friendliness (Sony, 2006). Canon (2006) also gives preference to environmentally friendly suppliers for its procurement. Also, in the US, paper and pulp industry firms tend to pay substantial costs to overcomply (see, e.g., McClelland and Horowitz, 1999).

[8] We note that significant fluctuations (variation) in the demand for firms' products, a source of major uncertainty in firm operations, increase environmental risks. One of the variables we use to represent uncertainty below is based on this idea.

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The rest of this paper is organized as follows. In the next section, we first discuss firms' economic decisions on whether or not to certify under ISO 14001. We then present our empirical models for estimation. In the third section we discuss our data. In the fourth section we present our empirical results. The paper concludes in the fifth section.

Our Model

Firms' decisions to acquire ISO 14001 certifications at their specific establishments depend on various factors. This is so because, as discussed above, ISO 14001 as well as other EMS certification schemes focuses on certifying firms' operations as being subjected to well defined environmentally sound production and other operational processes. However, there are a variety of circumstances in which firms cannot necessarily set up environmentally sound production processes, as required by ISO 14001. For example, when firms expect in their establishments' complex operations a significant number of situations that require specialists' interventions, then they may decide that such frequent interventions cannot be consistent with ISO 14001 in the context of firm profit maximization.[9] It is the high degree of complexity that is contained in the operations at firms' establishments that characterizes this situation.

On the other hand there are certain types of production activity that firms find suitable for ISO certifications. Many firms recognize the unpredictable nature of environmental risks associated with their operations, even though such operations are routine. Given the substantial financial loss that might arise from an environmental disaster, many firms consider various types of insurance policy to cope with such risks. Environment is an integral part of many firms' risk management (Reinhardt, 1999a, 1999b).[10]

It is then quite possible that rational firms use environmental management systems such as ISO 14001 as an insurance scheme for coping with the type of uncertainty arising from potential risks. In terms of management, schemes such as ISO 14001 will make firms' employees more aware of potential problems in daily operations that might lead to risks and hence will allow firms to reduce the probability of environmental and other problems.

These risk considerations suggest that another factor in environmental management that may cause firms to adopt 14001 certifications is the high degree of uncertainty present in firms' operations. We expect that large amounts of uncertainty in firms' operations, regardless of its sources, will likely increase environmental risks in general. We summarize our discussion above in the following hypotheses.

(H1) Firms are more likely to obtain ISO 14001 certifications for their operations when the degree of complexity contained in such operations is small.

(H2) Firms are more likely to obtain ISO 14001 certifications for their operations when the degree of uncertainty contained in such operations is large.

Probit Model

The conditions under which a firm pursues EMS certification is assumed to be approximated by the following probit model, where P( ) and PAI( ) represent the probability that firm i pursues EMS certification and the standardized normal distribution function, respectively:

[9] This type of situation may occur in dealing with complex product development or manufacturing processes.
[10] The recent notebook computer battery fiasco at Sony has cost Sony at least half a billion dollars so far (as of October 2006), and many expect further losses for Sony are inevitable. The problem arose when some production runs at Sony Energy Devices (Sony's subsidiary) in Fukushima, Japan, produced defective lithium-ion batteries, which ended up being used in the laptop computers produced by major laptop computer manufacturers such as Dell, Toshiba, Lenovo, Fujitsu, Hitachi and Sony itself. Sony invented the lithium-ion battery, which now monopolizes laptop computer battery markets. As such the product has been highly profitable to Sony. (The defective batteries had metal impurities, which may cause fires in the computer itself.) Laptop computer makers are threatening to sue Sony for the lost profits. Incidentally, Sony Energy Device's four establishments all obtained ISO 14001 certifications in the late 1990s. In addition three establishments also obtained ISO 9000 certifications for quality control.

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$$P(ISO14001 = 1) = PAI(F(X_{1i}, X_{2ij}, X_{3ijk}; M_{ijk}, U_{ijk})) \quad (1)$$

where X_{1i}, X_{2ij} and X_{3ijk} each represent vectors representing firm-specific, plant-specific and industry-specific factors. (j is the index of a plant (establishment) firm i operates and k is the index of an industry.) M_{ijk} and U_{ijk} represent respectively the plant's operational complexity and uncertainty.

The expected signs implied by (H1) and (H2) for the variables of interest in our probit model are M (–) and U (+).

Hence, the expected signs for the two variables of our interest in relation to our hypotheses are as follows. (H1) Complexity: negative sign, i.e. increased complexity decreases the probability of ISO 14001 certifications. (H2) Uncertainty: positive sign, i.e. increased volatility increases the probability of ISO 14001 certifications. Using probit estimation, we estimate various forms of linear approximation to $F(\ )$ in (1). We discuss our variables used for estimating (1) and probit estimation results in the third and fourth sections, respectively.

Duration Model

We estimate duration models by which we identify the determinants of firms' waiting times until the dates of their adoption of ISO 14001 certifications for their establishments. We use the same set of explanatory variables for estimating these models as for probit models. Our duration model estimation results are presented in the fourth section.

Data

Sample

The basic observation unit of our sample for micro-level estimation is the plant (which is also called the factory, establishment or facility in this paper). Our original sample consists of 2418 plants for which we have plant-level data. These plants are owned by firms. We then eliminated the observations for which information on some of the relevant variables of our interest discussed below is not available. This resulted in a sample of 879 plants, which we used for our estimation tasks. These firms in our sample were listed in Japanese stock exchanges in 2001 and belonged to one of the following manufacturing industries: chemicals, iron and steel, general machinery, electrical machinery and transportation machinery (Toyo Keizai, 2001). These industries were chosen because our earlier investigation showed that these industries provide us with the largest variation in values of the variables of interest in this study. Our sample consists of only production facilities and does not contain service facilities such as sales offices and corporate headquarters. Focusing on production facilities but not on service facilities was necessary for this study, whose primary interest lies in ISO 14001 certifications at manufacturing plants. Finally, firms whose plants appear in our sample are all listed in Japanese stock exchanges. The primary reason for using listed firms is that accurate information about these firms is readily available from public sources. We first explain the dependent and independent variables used in this study. Table 2 shows descriptive statistics for these variables. Table 3 shows the correlation matrix for the variables used.

Variables

The independent variables used can be divided into two groups: (1) the variables that are of special interest for our investigation, i.e. the variables that measure the degrees of complexity and uncertainty of the industry sector to which our sample plants belong, and (2) other variables, which are used primarily for controlling for plant-specific, firm-specific and industry-specific characteristics relevant for our sample plants.

Dependent Variable

Our dependent variable is ISO14001, a dummy variable describing whether or not a plant has obtained an ISO 14001 certification prior to 1 January 2000. If the plant has been certified by this date, this variable is set equal to

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Variable	Obs. unit[a]	Variable definition	Mean	Std. dev.	Minimum	Maximum
ISO14001	F	(certified) = 1; = 0 otherwise	0.304	0.460	0	1
SIMPSON	S	Simpson's diversity index	8.357	4.543	1.992	20.355
VARN	S	output variation (absolute value)	0.272	0.284	0.033	1.650
PTN	S	pattern of directional changes in output	0.301	0.426	0	1
BETA	C	firm's uncertainty related to macro-economy	0.938	0.467	−0.260	3.649
STDER	C	firm's uncertainty related to firm-specific circumstances	0.107	0.032	0.051	0.321
COEV	C	firm's uncertainty related to firm-specific circumstances (standardized)	0.165	0.053	0.069	0.412
ISO9000	F	(ISO 9000 certified before ISO 14001) = 1; =0 otherwise	0.501	0.500	0	1
FAC_EMP	F	number of employees at plant (1000s)	0.571	0.978	0.001	8.186
FAC_K	F	stock of machinery and equipment at plant (1 trillion yen)	0.005	0.015	0.000	0.185
CO_EMP	C	number of employees of the company (1000s)	15.088	31.612	0.037	210.709
AGE	C	average age of employees of the company	39.362	2.5174	31.8	52.8
RDRT	C	R&D expenditure/sales	0.032	0.021	0	0.233
ADVRT	C	advertising expenditure/sales	0.004	0.010	0	0.135
HOUSE	S	household demand/total output	0.054	0.122	0	0.686
EXPORTS	S	export demand/total output	0.196	0.129	0.005	0.579

Table 2. Descriptive statistics, Japanese manufacturing firms and plants
The number of observations (sample size) is 879 for all variables.
[a] F denotes variables whose values were observed at the factory (plant) level. Similarly C and S denote variables whose values were observed at the firm and industry levels, respectively.

unity; otherwise, it is set equal to zero. Information about this variable was collected from the database of the Japan Accreditation Board for Conformity Assessment (2003).

Independent Variables of Interest

We use several variables that we think are likely to reflect the degrees of complexity and uncertainty facing our sample plants' operations. These are explained below.

(i) *Variable used to measure operational complexity: SIMPSON*. Simpson's diversity index, which is used to measure the species diversity of a biological community (Begon *et al*., 1996, pp. 681–683). In this study, SIMPSON is calculated for each industry sector to which a sample plant belongs. The formula used for SIMPSON is

$$D = \frac{1}{\sum_{i=1}^{S} p_i^2}$$

In this formula p_i represents the proportion of a species i in a community that has S distinct species. In our context, p_i represents the share of input a particular industry sector receives from industry sector i.[11] To calculate

[11] SIMPSON is equal to one (minimum value) when there is no diversity. For example, SIMPSON for industry 1 is one when $S = 2$ and $p_1 = 1$ and $p_2 = 0$, or $p_1 = 0$ and $p_2 = 1$. When $p_1 = p_2 = 1/2$, then it is equal to 2 (maximum for this two industry setup).

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	ISO14000	SIMPSON	VARN	PTN	BETA	STDER	COEV	ISO9000	FAC_EMP	FAC_K
ISO14001	1.000									
SIMPSON	−0.155	1.000								
VARN	0.070	−0.112	1.000							
PTN	0.000	0.010	−0.215	1.000						
BETA	0.194	0.034	0.267	−0.039	1.000					
STDER	0.092	−0.073	0.130	0.046	0.429	1.000				
COEV	0.175	−0.051	0.180	0.056	0.338	0.612	1.000			
ISO9000	0.135	0.110	−0.001	0.043	−0.014	0.037	0.083	1.000		
FAC_EMP	0.281	−0.218	0.047	−0.079	0.070	−0.025	0.008	−0.119	1.000	
FAC_K	0.149	−0.220	−0.044	0.039	0.002	−0.012	0.006	−0.053	0.517	1.000
CO_EMP	0.320	−0.150	0.063	−0.081	0.122	−0.083	0.097	−0.140	0.671	0.327
AGE	−0.063	0.020	−0.157	0.140	0.023	0.101	−0.064	0.052	−0.048	0.050
RDRT	0.150	0.066	0.210	−0.061	0.054	−0.114	0.000	0.051	0.192	−0.010
ADVRT	0.012	0.084	−0.024	0.083	−0.118	−0.123	−0.048	0.067	0.033	−0.011
HOUSE	0.126	−0.036	0.003	0.174	−0.051	−0.162	−0.074	0.059	0.168	0.021
EXPORTS	0.212	−0.155	0.282	−0.011	0.145	0.135	0.097	−0.140	0.356	0.043

	CO_EMP	AGE	RDRT	ADVRT	HOUSE	EXPORTS
ISO14000						
SIMPSON						
VARN						
PTN						
BETA						
STDER						
COEV						
ISO9000						
FAC_EMP						
FAC_K						
CO_EMP	1.000					
AGE	−0.089	1.000				
RDRT	0.286	−0.148	1.000			
ADVRT	0.061	−0.079	0.062	1.000		
HOUSE	0.206	−0.022	0.226	0.362	1.000	
EXPORTS	0.328	−0.237	0.247	0.050	0.191	1.000

Table 3. Correlation Matrix

p_i ($i = 1, 2, \ldots, 184$) we have used a Japanese input–output table consisting of (S=) 184 sectors (Ministry of Internal Affairs and Communications, c. 2005). The shares of these sectors are measured in monetary terms. In our interpretation, the larger the SIMPSON index of a sector, the greater is the complexity of that sector. We have identified our sample plant's industry using data provided by a commercial database company (Teikoku Data Bank, 2005). If there is a possibility that a plant belongs to several industry sectors and we can not determine the appropriate sector, a simple average value of the SIMPSON index values calculated for these suspected several sectors has been assigned to the variable. Since we hypothesize that a high degree of complexity deters EMS certification, we expect negative signs for coefficients of complexity variables obtained in our probit analyses.

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(iia) *First set of variables used to measure operational uncertainty: VARN and PTN.* VARN measures the amounts of change in output over two consecutive periods as follows:

$$VARN = \left|\frac{OUT_{i,1995}}{OUT_{i,1990}} - 1\right| + \left|\frac{OUT_{i,2000}}{OUT_{i,1995}} - 1\right|$$

where $OUT_{i,y}$ is industry sector *i*'s output in year *y*. $OUT_{i,y}$ is measured in real money terms with 2000 as the base year and is obtained from Japanese input–output tables for 1990, 1995, 2000 and 2005 (Ministry of Internal Affairs and Communications, c. 2005). Our sample plants' industry affiliations were determined in the same way as before and simple average values were used when a plant was suspected to belong to more than one industry.

VARN defined above merely captures the intensity of dynamic uncertainty associated with industry sectors' output. On the other hand the PTN variable defined below measures the directional patterns of uncertainty as well as discontinuity in such changes in patterns over time. The basic idea is that, if the directions of changes over time remain the same for a particular industry sector, factories in that sector will find it easier to plan for the future. In contrast, if the directions of changes over time keep changing, the factories in that sector will have a great deal of difficulty in planning for the future. We compare the directions of changes between two consecutive periods, namely 1990–1995 and 1995–2000. If an industry sector consecutively decreases or increases its output (in real money terms), we set PTN, a dummy variable, equal to zero; otherwise we set it equal to unity. So PTN = 1 when a particular industry sector's output went up (down) in the 1990–1995 period and went down (up) in the 1995–2000 period. The input–output tables used for calculating VARN were also used to calculate PTN. We also used the same procedure for determining our sample plants' industry sector affiliations as before.

Since we hypothesize that greater uncertainty promotes ISO 14001 certification, we summarize that these two variables as well as their product term will have positive coefficients in our probit regressions.

(iib) *Second set of variables used to measure operational uncertainty: BETA, STDER, COEV.* BETA here is the firm's *beta* (systematic risk) calculated from the firm's and (Japanese) market stock returns.[12]

STDER denotes the standard error (firm-specific risk) associated with the firm's stock return after removing systematic risk.

COEV denotes the coefficient of variation of firm-specific risk.

BETA measures a particular type of correlation between firm's and market stock returns and represents undiversifiable risk (i.e. systematic risk associated with the Japanese economy) inherent in a particular company's business. Thus, in terms of undiversifiable risk, firms with beta >1 are thought to be more risky than the market while firms with beta <1 are less risky than the market. STDER measures firm-specific business risks, which the potential investors in this firm can diversify away by owning a portfolio of stocks in other firms. We expect this variable to reflect uncertainty arising from firm-specific environmental risks that the firm's industry peers do not suffer from. COEV represents firm-specific business risk standardized by the standard deviation of firm's stock return.

We expect these firm-specific variables introduced here to represent the types of uncertainty associated with the firms' operational environments. Since we hypothesize that greater uncertainty promotes ISO 14001 certification, we expect that these firm-specific variables will have positive coefficients in our probit regressions.

Independent Variables Used for the Purpose of Controlling for Plant-Specific, Firm-Specific and Industry-Specific Factors

Plant-specific variables

ISO 9000. Many establishments in Japan and throughout the world have obtained ISO 9000s quality management system (QMS) certifications. The experiences firms have accumulated from ISO 9000s QMS certification

[12] We regress y_j (time series of company stock returns for 30 months up to December 2001) on x_j (time series of market return for 30 months up to December 2001), where all returns are dividend adjusted and market return here is the weighted average returns for all stocks listed in the Tokyo Stock Exchange. The estimated slope is the firm's beta.

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and maintenance processes are known to be useful for obtaining ISO 14001 EMS certifications.[13] A number of previous studies have found that ISO 9000s QMS certification is a statistically significant antecedent of ISO 14001 EMS certification (Nakamura *et al.*, 2001). For this reason, we have included the ISO 9000s dummy variable as an independent variable in our statistical model. This dummy variable, ISO9000, is set equal to unity if a factory had obtained ISO 9000s certification before getting certified for ISO 14001; otherwise, we set it equal to zero. Data for this variable was obtained from the database of the Japan Accreditation Board for Conformity Assessment (Japan Accreditation Board for Conformity Assessment, 2003). Since having acquired ISO 9000 series QMS certifications makes it easier to obtain ISO 14001 certifications, we expect the ISO9000 dummy to have a positive sign in our probit analysis.

FAC_EMP and FAC_K. Previous studies have identified that size matters in firms' decisions on environmentally friendly actions (e.g. Nakamura *et al.*, 2001). This is because environmentally friendly actions such as obtaining and maintaining ISO 14001 certifications, as discussed before, are relatively expensive, and larger size for firms and establishments would be helpful for firms in pursuing such actions. We use two factory-level variables to measure factory's size. The size of the factory's workforce (number of workers) is given by FAC_EMP and the value of capital stock (book value of factory's stock of plant and equipment) is given by FAC_K. Information on both of these variables was collected from Nikkei's company directory (Nihon Keizai Sinbunsya, 2003). Since we hypothesize that size helps in obtaining 14001 certifications, we expect these variables to have positive signs in our probits.

Company-specific variables

CO_EMP. CO_EMP measures the size of the company's workforce (number of workers). As for size variables for factories, we expect firm size to have positive signs in our probit regressions. Information on CO_EMP was collected from company data books (Toyo Keizai, 2001, 2002).

AGE. It was found that the average age of the company's workforce (AGE) is an important determinant of 14001 certifications (Nakamura *et al.*, 2001). A hypothesis put forward in the literature is that, compared with firms with older employees, progressive firms with younger employees are more likely to attempt new business practices such as 14001 EMS certification. Since our certification data are measured at the plant level, it is not clear that the expected sign (a positive sign) from firm-level studies will carry over. Information on this variable was collected from Toyo Keizai (2001, 2002).

RDRT. Since firms' R&D–sales ratios were found to be positively correlated with their ISO 14001 certification decisions in a number of previous studies at the firm level, information for this variable was collected from Toyo Keizai (2001, 2002). RDRT is thought to represent firms' accumulation of knowledge capital. It is hypothesized that firms with greater knowledge capital would find it much easier to adopt newer practices such as new environmental management systems (Ghemawat, 1986). Anton *et al.* (2004) also suggest a positive correlation between RDRT and comprehensiveness of the EMS.

ADVRT. Several firm-level certification studies found that firms whose product markets are close to the final consumers are likely to pursue environmentally friendly actions, compared with firms whose product markets are distant from the final consumers. If so, then firms whose markets are close to their final consumers tend to feel a greater need to secure their consumers' goodwill and are hence more likely to opt to seek 14001 certifications (Nakamura *et al.*, 2001). We use ADVRT, the ratio between firms' advertising expenditures and sales revenues, to capture such effects. Information for this variable was collected from Toyo Keizai (2001, 2002) and Nikkei Koukoku Kenkyuusyo (2001). Since this study uses certification data at the plant level, it is not clear whether we can expect a positive sign for this variable in our probits.

[13] For example, prior experience with ISO 9000 may reduce the implementation cost of ISO 14001. We should also note that, like ISO 14001 certifications, ISO 9000 does not guarantee product quality. It certifies the presence of quality control processes at organizations.

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Industry-specific variables
HOUSE. HOUSE is used to measure the distance between firms and their final consumers at the industry sector level. (On the other hand, ADVRT above measures the same distance at the firm level.) HOUSE is calculated as the proportion of household consumption to a particular industry's total output. We used data from the Japanese 184 sector input–output table for the year 2000 (Ministry of Internal Affairs and Communications, c. 2005) to calculate HOUSE. Using the same reasoning as for ADVRT, we expect that HOUSE will have a positive sign in our probits.

EXPORTS. Considerable empirical evidence exists that export demand is an important driving force of firms' decisions to obtain ISO 14001 certifications (e.g. Nakamura *et al.*, 2001). EXPORTS measures the extent of export demand that a particular industry sector faces and is calculated as the proportion of exports to the total output of that industry sector. We have used the Japanese 184 sector input–output table for the year 2000 (Ministry of Internal Affairs and Communications, c. 2005) to calculate this variable. We expect EXPORTS to have a positive sign in our probits.

The sample we used for model estimation consists of 879 observations on plants for which all appropriate data exist. Tables 2 and 3 respectively contains descriptive statistics and a correlation matrix for this sample.

Empirical Results

Probit Estimation Results

The objective of this study is to empirically ascertain our hypotheses (H1) and (H2) that complexity of their operations deter firms from obtaining ISO 14001 certifications while uncertainty in their operations encourage firms to obtain ISO 14001 certifications. As we have seen in the previous section, our source of information on the degrees of complexity and uncertainty at plant level operations is rather limited. Nevertheless our variables of interest, SIMPSON, VARN and PTN, to measure complexity and uncertainty have sound theoretical basis and have been calculated using detailed industry sector input–output data. In this sub-section we present our probit regression results using the sample of our plant-level data (Table 4).

Survival function Form	Model 1 (containing SIMPSON, VARN and PTN as the explanatory variables to capture operational complexity and uncertainty)			Model 2 (containing SIMPSON, BETA, STDER and COEV as the explanatory variables to capture operational complexity and uncertainty)		
	Log likelihood	No. of parameters	AIC[1]	Log likelihood	No. of parameters	AIC[1]
Logistic (Models D1 and D2 in Table 5)	−740.9179	14	1509.836	−724.421	15	1478.843
Weibull (Models E1 and E2 in Table 5)	−755.8618	14	1539.724	−745.26	15	1520.519
Normal	−756.6427	14	1541.285	−740.885	15	1511.769
Generalized *F*	−769.9736	16	1571.947	−757.505	17	1549.009
Exponential	−867.5483	14	1763.097	−859.661	15	1749.322

Table 4. Choosing among alternative duration models using the Akaike information criteria
[1] Models with smaller AIC values are preferred.
[2] Another functional form, the gamma distribution, was also estimated, but the algorithm did not converge because of singular Hessian matrices.

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Our first set of estimation results is probit regressions based on plant-level data collected for large listed firms in Japanese manufacturing industries. The dependent variable (ISO14001) is a dummy variable representing whether or not ISO 14001 has been acquired at the plant by 1 January 2000. This dummy variable was regressed on a variety of explanatory variables using probit models. Our variables of interest, complexity and uncertainty, are both measured in two alternative ways at the industry level (SIMPSON for complexity, and VARN and PTN for uncertainty.) At the firm level, uncertainty is measured by alternative variables, BETA, STDER and COEV. As discussed above, we have also included certain variables that previous research found affect firms' decisions on ISO 14001 certifications.

Our probit results are presented in Table 5 (C-1 and C-2). We first note that the likelihood ratio test statistics for our estimated models are all statistically highly significant (at least at a 0.1% significance level). *R*-squared measures of fitness of our models range from 0.167 (Maddala R^2) to 0.274 (Cragg–Uhler R^2). Given the diverse types of plant included in our sample, we expect high variability in the probit error terms. For these reasons we feel these observed model *R*-squared values are reasonable.

The Variables of Interest

The most striking result is that our complexity variable, SIMPSON, has negative sign and is statistically highly significant. This is consistent with our expectations and confirms this part of our hypothesis (H1). As well, our uncertainty variables, BETA and COEV, have statistically significant coefficients, which have the expected positive signs. This probit result provides empirical evidence that supports our hypotheses H1 and H2. Sectoral-level variables, VARN and PTN, do not have significant coefficients, however.

Thus, our empirical results provide reasonable support to the first hypothesis (H1), that sectoral-level operational complexity decreases the likelihood for plants to seek ISO 14001 certifications, and our second hypothesis (H2), that firm-level operational uncertainty increases the same likelihood, is also supported.

Control Variables

Three variables that are statistically highly significant with expected signs in our probit model are ISO9000, CO_EMP and EXPORTS. This means that our reasons discussed earlier for including these variables as our control variables are justified. We also note that factory workforce size variable (FAC_EMP) and factory capital stock size variable (FAC_K) are not statistically significant (at a 10% level). We speculate that the firm size is a better variable to represent firms' capacity to cope with ISO 14001 certification decisions. There are also other control variables that did not turn out to be statistically significant. These include FAC_K, RDRT, ADVRT, HOUSE and AGE. At this time we do not have a good explanation for the behavior of these variables.

We point out particularly that the dependency on foreign markets was found to be correlated with a facility's decision to seek ISO 14001 certification. This confirms the claim that the pressure from foreign markets, directly or indirectly, encourages Japanese factories to seek ISO 14001 certification.

Duration Analysis: Estimation Results

In the duration analysis we define the dependent variable, SRISO14, to be the amount of time elapsed between some reference point in time (12 September 1995 in our case, when Japan's first ISO 14001 certification was obtained) and the actual point in time when a particular establishment gets ISO 14001 certification. Thus SRISO14 represents the point in time when the event of certification occurs. SRISO14 is thought to vary systematically as a function of various explanatory variables. Generally, we expect the factors that promote firms' certification decisions to shorten the amounts of time that firms wait before they decide to certify particular establishments.

Depending on what types of statistical distribution we assume for the underlying distribution of the waiting time (called the survival function), estimation results differ slightly, but, in our empirical analyses, we have obtained qualitatively similar results. Using the standard Akaike information criterion (AIC) used to discriminate non-nested models, we find, as shown in Table 4, that the logistic distribution model fits our data best, followed by the Weibull distribution.

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	Probit model estimates		Duration analysis estimates (logistic models)		Duration analysis estimates (Weibull models)	
	C-1	C-2	D-1	D-2	E-1	E-2
SIMPSON	−0.039	−0.041	0.016	0.018	0.019	0.018
	3.382***	3.614***	2.782***	3.041***	3.510***	0.001***
VARN	0.024	–	−0.095	–	−0.070	–
	0.137		1.051		0.913	
PTN	0.100	–	−0.077	–	−0.137	–
	0.827		1.150		2.172**	
BETA	–	0.408	–	−0.144	–	−0.080
		3.424***		2.343**		1.551
STDER	–	−0.779	–	−0.083	–	−1.098
		0.357		0.074		1.144
COEV	–	2.874	–	−2.085	–	−1.256
		2.413**		3.490***		2.384**
ISO9000	0.631	0.600	−0.576	−0.548	−0.584	−0.567
	6.291***	5.888***	10.88***	10.70***	10.74***	10.52***
FAC_EMP	0.095	0.113	−0.040	−0.055	−0.023	−0.024
	1.245	1.471	1.215	1.726*	0.984	1.067
FAC_K	1.768	2.384	−1.667	−1.666	−0.943	−1.898
	0.477	0.636	1.055	1.068	0.634	1.283
CO_EMP	0.012	0.010	−0.007	−0.006	−0.006	−0.005
	4.830***	3.979***	7.674***	6.195***	8.716***	7.291***
AGE	−0.019	−0.019	0.007	0.004	0.000	0.004
	0.936	0.914	0.580	0.346	0.020	0.405
RDRT	2.563	3.144	−1.038	−1.641	−0.161	−0.094
	1.026	1.255	0.777	1.291	0.125	0.076
ADVRT	−4.937	−1.987	3.671	2.156	3.094	2.038
	0.834	0.339	1.043	0.667	0.936	0.691
HOUSE	0.332	0.589	−0.517	−0.675	−0.541	−0.753
	0.747	1.328	2.174**	3.063***	2.933***	4.420***
EXPORTS	1.152	0.847	−0.297	−0.153	−0.416	−0.332
	2.650***	1.953**	1.261	0.685	2.032**	1.601
CONSTANT	−0.406	−1.101	4.550	5.071	4.992	5.173
	0.486	1.293	9.808***	11.24***	11.75***	13.14***
Sigma			0.381	0.371	0.497	0.494
			26.59***	27.04***	22.72***	22.92***
Sample size	879		879		879	
ISO14001=1	267		267		267	
LR test (No. parameters)	0.000	0.000	−740.918 (14)	−724.421 (15)	−755.862 (14)	−745.260 (15)
Maddala R^2	0.167	0.194				
Cragg–Uhler R^2	0.237	0.274				
Akaike information criterion			1509.836	1478.843	1539.724	1520.519

Table 5. Probit and duration analysis results
Numbers under coefficients are absolute t-ratios.
[a] *, ** and *** denote, respectively, statistical significance at 10, 5 and 1% levels.

We see that, in duration regression models based on logistic survival functions (D-1 and D-2), the variables that are statistically significant have the expected signs.[14] In particular, the two quantities of interest, complexity (SIMPSON) and uncertainty (BETA and COEV), are both statistically significant and have the expected signs, thus confirming that firms seek ISO 14001 certifications for plants with more routine operations and also for plants for which more uncertain business circumstances are present. These duration analysis results are consistent with our hypotheses H1 and H2. Our estimation results based on Weibull survival functions (models E1 and E2) are similar, but their fit is less good than for the models assuming logistic survival functions.

The implications of logistic and Weibull survival functions are as follows. Under the logistic form, the hazard (i.e. likelihood that a not-yet-certified plant receives ISO 14001 certification) increases rapidly as time passes to a peak and then starts to decline after reaching the peak.[15] The speed with which the peak is reached depends on the parameter sigma, which is estimated to be 0.381 (for model D-1) and 0.371 (for model D-2) from Table 5.[16] On the other hand, the hazard under Weibull distribution increases exponentially (e.g. when sigma = 1), increases linearly (e.g. sigma = 0.5) or decreases exponentially (e.g. sigma = 2). Our estimates for Weibull's sigma are 0.497 (for model E-1) and 0.494 (for model E-2), thus suggesting that the hazard increases linearly as time passes. To the extent that the logistic form gives the better fit to the data, we conclude that, after controlling for the included explanatory variables, the hazard increases with time rapidly first but then declines after the peak is reached.[17]

Acceptance of the logistic hazard implies that firms certify first the plants that are easier to certify at an accelerated rate. After the peak of certification is reached, the rate at which such certifications are carried out becomes slower over time, even though the firms may continue to certify the remaining plants. This is consistent with our view that firms prioritize the order with which to certify their plants.

Concluding Remarks

In this paper we have argued that cost-minimizing and risk-averse firms decide to seek ISO 14001 environmental management certifications based on two considerations: (1) the cost of certification based on the degree of complexity of their operations (i.e. routine operations are certified first) and (2) the benefit of using ISO 14001 as an insurance scheme against the uncertain, but major, environmental risks that might be inherent in their operations. Such economic decisions by firms seem plausible because of the known high costs associated with applications for and maintaining such certifications over time on one hand, and the potentially high cost of uncertain environmental disasters that might occur on the other.

We have put forward two hypotheses about whether or not and when firms choose to seek ISO 14001 certifications. These hypotheses are first, that firms choose to certify plants when operations of the plants involve low degrees of complexity, and, second, that firms choose to certify plants when operations of the plants involve high degree of uncertainty. We have empirically tested these hypotheses using probit and duration models using data on Japanese manufacturing plants. We have found empirical support for these hypotheses.

Policy Implications

Researchers have suggested alternative methods by which corporations are to discharge their corporate social responsibilities in coping with societal environmental concerns. For instance, Coglianese and Nash (2001) discuss the possibilities of EMSs as a policy instrument for performance-based regulation rather than the currently prevalent technology-based regulation. Governments of many developed and developing nations have also suggested that firms adopt ISO 14001 certifications, among other environmental management systems, for enhancing

[14] Note that the expected signs for duration analyses are opposite to those of probits.
[15] The hazard function is defined by the ratio between the probability density function and the corresponding distribution function (which is the survival function).
[16] When sigma is equal to or greater than one, the logistic hazard monotonically decreases like an exponentially decreasing function.
[17] See Joyce (2005) for a similar analysis of the duration model estimation results in the context of country-specific program spells of the International Monetary Fund programs.

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their global competitiveness. For example, the Japanese government adopted ISO 14001 certifications into the laws specifying the Japanese Industrial Standard (JIS) system (Japanese Industrial Standards Committee, 2008) and promotes it to Japanese firms (Japanese Ministry of Environment, 2007). Given this, Japanese firms often consider adoption of ISO 14001 and other EMSs essential for satisfying green procurement requirements in both the private and public sectors.[18] Our findings lead to a few policy implications for environmental policymakers and business practitioners.

First, where policymakers consider using voluntary environmental management systems such as ISO 14001 as an alternative policy tool for improving firms' environmental performance, our findings suggest that policymakers need to pay attention to the fact that environmental management systems are suitable for relatively simple operations. This implies that firms do not necessarily welcome policy initiatives requiring application of environmental management systems to their facilities with complex operations. It is important, then, for policymakers to examine the fit between EMSs and the complexity of operations of the industry sectors to which application of the EMSs is being considered.

Our suggestions for business practitioners who are now facing the challenges of adapting EMSs to complex processes are that successful application of EMSs to complex operations would require at least some adjustments in EMS practices and that, for some circumstances, it might be necessary to adopt alternative principles other than EMSs for satisfying the firms' environmental objectives.

We can identify several alternative ways of corporate greening when standard EMSs are not suitable for the firm's operational characteristics. Tailoring EMSs according to the firm's characteristics (Williams *et al.*, 2000) or developing a sector strategy (Holton *et al.*, 2008) may represent practical options for such companies. Otherwise, more individual-oriented, champion-centered corporate greening may help such companies pursue their objectives more effectively (Fernandez *et al.*, 2006). Future research into these possibilities may contribute to the development of corporate greening without EMSs.

Second, our results that uncertainty inherent in their operations encourages firms to seek ISO 14001 certifications is consistent with the notion that an EMS serves as an insurance tool for many manufacturers in their risk management practices. Clearly environmental policymakers could use these findings to encourage firms operating with uncertain but potentially disastrous environmental risks to undertake EMS certifications.

We should note that the empirical results presented here are tentative in that the variables we have used to capture complexity and uncertainty associated with firms' plant operations need further refinement. In particular, the two variables we have used to capture operational uncertainty, VARN and PTN, are likely to be inadequate for capturing the types of information we would like to capture with respect to plants' operational uncertainty. We note that VARN and PTN both measure *ex post* changes in output. However, firms' decisions on ISO 14001 certifications would be affected by *ex ante* uncertainty, not *ex post* uncertainty, that faces their plant operations. Finding appropriate variables and data to capture such *ex ante* information is left for future research.

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[18] Japan's law concerning green purchasing (enacted in 2000) was implemented in 2001.

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