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ORIGINAL ARTICLE

Voluntary development of environmental management systems: motivations and regulatory implications

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Abstract Encouraging firms to develop voluntarily more comprehensive environmental management systems (EMSs) is touted as a policy tool to augment mandatory environmental regulations. Using a unique dataset of environmental management practices of Japanese manufacturers and controlling for self-selection bias in survey responses, we find that proxies for regulatory pressures and consumer pressures are the most important factors that motivate firms toward more comprehensive EMSs. Despite the oft-claimed "voluntary" nature of EMS development, our results show that the government may have a role to play in both directly and indirectly affecting EMS development by firms.

Keywords Environmental management · Japan · Pollution · Voluntary approaches

JEL Classifications Q5 · L5

1 Introduction

Voluntary approaches to environmental protection are sometimes called the "next generation of environmental policies" (Esty & Chertow, 1997). In contrast

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to mandatory policies such as direct regulations and environmental taxes, these approaches rely on voluntary actions of firms to improve their environmental performances beyond legal requirements. Examples include unilateral commitments by firms (business-led corporate environmentalism), public voluntary programs in which regulatory authorities design a program and encourage firms to voluntarily achieve specified goals, and joint initiatives between governments and a group of polluters (Carraro & Leveque, 1999). Proponents argue that voluntary approaches bring cost-savings over mandatory policies for regulators, while encouraging firms to take holistic strategies to improve their environmental performances (Khanna, 2001; Lyon & Maxwell, 2004). Such characteristics are particularly attractive when regulatory authorities face tight budgets and increasing pressures to find cost-effective policy tools (Lyon & Maxwell, 2004).

The last decade has witnessed a dramatic increase in voluntary development of environmental management systems (EMS). For example, the number of ISO 14001 certifications has grown more than 7 times during the period of December 1999 and December 2004 (ISO, 2005).[1] An EMS is a collection of systematic management practices aimed at creating internal forces that ensure continual improvement of overall environmental performances (Martin, 1998). Although the comprehensiveness of EMSs varies across firms, most EMSs are based on a "plan, do, check, act" model. This model typically involves establishing plans or objectives to identify the need for environmental improvement, implementing plans by assigning directors and training employees, checking progress through monitoring and auditing systems, and analyzing outcomes and modifying the EMS for further improvement (Coglianese & Nash, 2001). There are conceptual reasons for believing that EMSs are critical in improving overall environmental performances of firms. Without having comprehensive EMSs, firms are unlikely to take systematic approaches for improving their environmental performances including activities not directly regulated by laws (Coglianese & Nash, 2001; U.S. EPA, 1999). In addition, recent empirical studies found that development of EMSs leads to better compliance status (Dasgupta et al., 2000) and lower toxic emissions per unit output (Anton, Deltas, & Khanna, 2004).

Actively encouraging EMS development through offers of technical assistance, cost-sharing, and public recognition has recently been described as a potential policy tool to augment mandatory environmental regulations in OECD nations (Crow, 2000; OECD, 2003; Rondinelli, 2001; U.S. EPA, 2004). In the United States, the Environmental Protection Agency (EPA) launched the National Environmental Performance Track, which aims to find a cost-effective way to encourage firms to develop more comprehensive EMSs and achieve higher levels of environmental performance (Lyon & Maxwell, 2002). To be eligible for the program, a facility must have sufficiently developed EMSs along

[1] ISO 14001, created by the International Organization for Standardization (ISO), offers guidelines for developing EMSs. In order to receive certification, organizations must implement procedures that follow the ISO14001 guidelines (certification is not based on actual environmental performances).

with a history of commitment to regulatory requirements and continual environmental improvement. In return, participants receive public recognition, less frequent regulatory inspections, and flexibility in terms of timing and methods for meeting regulatory standards.

As this example illustrates, encouraging the development of EMSs is typically discussed in the context of finding a cost-effective way to augment, but not to substitute, existing regulations (OECD, 2003; U.S. EPA, 2004). Since development of EMSs is voluntary, however, not all firms may voluntarily develop comprehensive EMSs. Indeed, there are significant variations across firms in the comprehensiveness of their EMSs. Before promoting and relying on firms' voluntary development of EMSs, regulators must understand the factors that motivate firms to develop EMSs on their own. Without such information, regulators will be unlikely to effectively design and target incentives in a way that leads to an increase in the use of EMSs.[2] For example, if consumer pressures promote EMS adoption, public recognition may provide appropriate incentives. If weak financial status hinders EMS development, financial rewards or low interest financing may be necessary. If weak technical capacity is a key constraint, technical assistance can help.

There exist informal analyses and anecdotal evidence of the factors that motivate firms to develop EMSs, but formal econometric analyses are still relatively scant (Lyon & Maxwell, 2004). These empirical studies (Anton et al., 2004; Dasgupta et al., 2000; Henriques & Sadorsky, 1996; Khanna & Anton, 2002; Nakamura, Takahashi, & Vertinsky, 2001; Welch, Mori, & Aoyagi-Usui, 2002) tend to agree on the importance of pressures from shareholders and governments, but they return mixed results on the effects of consumers, industry structure, and financial status of firms (Lyon & Maxwell, 2004).

Our study adds new empirical evidence on the factors that motivate firms to develop EMSs and extends previous research in two important ways. First, we examine the factors that determine the comprehensiveness of a firm's EMS, rather than the adoption of a single environmental practice. With the exception of Khanna and Anton (2002), studies of EMSs have focused on a single aspect of environmental management practices or systems.[3] Successful environmental improvement, however, requires a systematic and integrated effort of planning, implementation, and monitoring (Denton, 1994). Thus, it is informative to investigate the determinants of variations in the comprehensiveness of EMSs rather than the adoption decision of a single environmental practice. We draw on a unique dataset from a survey that examined environmental management practices of Japanese manufacturing firms and analyze the determinants of

[2] We acknowledge that future research must identify the conditions under which voluntary approaches are likely to be cost-effective compared to mandatory policies. Although we do not directly answer this question, we believe our study is a step in the right direction because voluntary approaches are unlikely to be cost-effective unless regulators appropriately design incentive schemes in a way that leads to an increase in the use of EMSs.

[3] Dasgupta, Hettige, & Wheeler (2000) analyzed the determinants of four environmental practices separately and did not study the determinants jointly. Anton, Deltas, & Khanna (2004) used the same dataset as Khanna and Anton (2002).

comprehensiveness of EMSs. There are no nation-wide programs in Japan that encourage firms to voluntarily develop EMSs and thus we study factors that motivate firms to develop EMSs on their own.

Second, our study is the first that controls for self-selection in econometric estimation. The existing studies (Anton et al., 2004; Dasgupta et al., 2000; Henriques & Sadorsky, 1996; Khanna & Anton, 2002; Nakamura et al., 2001; Welch et al., 2002) used firm-level survey data on environmental practices, but none of them controlled for self-selection in survey responses. Firms with poorly developed EMSs may be less likely to respond to the survey because responding to the survey may reveal their poor performances and may lead to bad publicity. Although self-selection by non-response is always an issue in surveys, it is typically difficult to control for it because of the absence of requisite data. We take advantage of the characteristics of our dataset and econometrically control for non-response bias.

In addition to these two contributions, we also analyze the motivations behind the development of subsets of EMS practices. Motivations may differ across these subsets and understanding these motivations can shed additional light on EMS development.

The rest of the paper is organized as follows. Section 2 presents the hypotheses on the factors that determine the comprehensiveness of a firm's EMS and defines the variables that are used to test the hypotheses. Section 3 describes the data and empirical methods. Section 4 presents the results and discusses policy implications. Section 5 concludes the paper.

2 Hypotheses and measures

2.1 Hypotheses

Theoretical studies on voluntary approaches postulate that although some firms take voluntary actions to improve their environmental performances, their actions are still based on profit-maximization (Arora & Gangopadhyay, 1995; Lutz, Lyon, & Maxwell, 2000; Maxwell, Lyon, & Hackett, 2000; Segerson & Miceli, 1998). In the context of EMS development, firms may choose their desired level of EMS to maximize their profit. If so, firms develop EMSs as long as expected benefits exceed expected costs. Expected benefits may include reduced risk of liabilities, competitive advantages in green markets, increased efficiency in input use, and improved investor relations. Expected costs may include training of personnel, investment in new machines and technologies, and hiring consultants (Stapleton, Glover, & Petie Davis, 2001).

We hypothesize that the following five factors affect expected benefits and costs, and therefore explain why firms develop EMSs: stakeholder pressures, regulatory pressures, ability, parent company's influence, and market conditions. We explain the rationale for these factors below and then, in Sect. 2.2, we describe how we will measure these factors.

(1) *Stakeholder pressures*

Stakeholder pressures include pressures from consumers and shareholders. Numerous surveys have shown that consumers make decisions with an awareness of their environmental impacts. Arora & Gangopadhyay (1995) argued that consumers can create incentives (pressures) for firms to be environmentally friendly. In the presence of environmentally conscious consumers, firms can command a price premium in the product market by establishing themselves as environmentally friendly. Therefore, firms with stronger contact with consumers may have greater incentives to develop EMSs to publicize their environmental activities and attract green consumers. Empirically, consumer pressures were found to be important in motivating the adoption of an environmental plan in Canada (Henriques and Sadorsky, 1996) and environmental practices in the U.S. (Anton et al., 2004; Khanna & Anton, 2002), but were found to explain only some aspects of ISO 14001 adoption among Japanese firms (Nakamura et al., 2001). In this study, we hypothesize that firms in closer contact with consumers develop more comprehensive EMSs.

Shareholders can also create pressures. The efficient market hypothesis predicts that a firm's current stock price reflects investors' beliefs about the firm's future profitability. If investors believe that the absence of a well-developed EMS implies lower future profits for a firm, they will bid down the stock price, which would put pressures on the firm to develop an EMS (Hamilton, 1995). Individual investors may also have preferences for environmentally-friendly firms, as evidenced by the increasing popularity of socially responsible investment funds. Therefore, firms that heavily rely on capital markets may receive stronger pressures from general investors to develop EMSs (Khanna and Anton, 2002). On the other hand, investors may perceive EMSs as unnecessary expenditures that will reduce profitability. Thus, in this study we leave the impact of investor pressures as an empirical question. In addition to general investor pressures, we also investigate if firms with higher ratio of foreign shareholders develop more comprehensive EMSs. Foreign shareholders, especially those in Europe and North America, may have stronger preferences for environmentally-friendly firms than the average Japanese investor. Therefore, firms may receive greater pressures to develop EMSs if a group of shareholders has a higher ratio of foreign owners. Empirically, both Khanna and Anton (2002) and Henriques and Sadorsky (1996) found that shareholders are important in motivating firms to take proactive actions, but neither study explicitly separated domestic shareholders and foreign shareholders.

(2) *Regulatory pressures*

A key feature of voluntary approaches is that firms will not be forced to bear unwanted costs. Although firms are not forced to develop EMSs, the threat of regulatory pressures may motivate firms to voluntarily develop EMSs. Firms may develop EMSs to achieve better compliance status with the current and future regulations or to strategically react to the threat of future regulations. Several theoretical studies have postulated that firms employ unilateral initiatives to preempt future regulatory threats (Maxwell et al., 2000;

Segerson & Miceli, 1998) or to weaken forthcoming new regulations (Lutz et al., 2000). Past empirical studies also found regulatory pressures to be an important driver for voluntary adoption of environmental practices. Perceived regulatory pressures were found to motivate firms to adopt ISO 14001 (Nakamura et al., 2001) and an environmental plan (Henriques and Sadorsky, 1996). Existing and anticipated regulatory pressures were also found to be important (Khanna and Anton, 2002). We hypothesize that firms under stronger regulatory pressures develop more comprehensive EMSs.

(3) *Ability*

Technical ability and financial ability can affect the ease with which firms develop EMSs. Unlike traditional regulations, firms are not required to adopt specific pollution control technologies in voluntary development of EMSs. Therefore, firms may need to use their technical knowledge to design and implement management practices aimed at environmental improvement (Coglianese & Nash, 2001). In general, manufacturing firms with better technical knowledge are more able to successfully adapt their management practices to changing business environments (Rugman & Verbeke, 1998). Thus, firms with better technical knowledge may be more able to develop EMSs. Empirically, Khanna and Anton (2002) found that R&D expenditures positively affect firm adoption of environmental practices in the United States, while Nakamura, Takahashi, & Vertinsky (2001) found the effect is negative on ISO 14001 adoption among Japanese firms.

The financial health of firms can affect the ability of firms to develop EMSs. For example, a 1999 survey conducted in the U.S. found that start-up costs are a major constraint to adoption of ISO 14001 (Delmas, 2000). Therefore, firms with poor financial status may be less able to make investments in EMSs. On the other hand, firms may develop EMSs regardless of financial status if doing so is profitable.[4] Empirical evidence on financial health is mixed. While Henriques and Sadorsky (1996) found no evidence, Nakamura, Takahashi, & Vertinsky (2001) found that a higher debt ratio has a significantly negative impact on ISO 14001 adoption.

Variability among firms in their start-up costs is another important aspect of financial ability. Firms with lower costs of investment are likely to have a higher ability to develop EMSs. Khanna and Anton (2002) claim that age of assets affect costs of investment. The rationale is that firms with older equipment may find it less costly to replace old equipment when making a start-up investment in new facilities. However, newer facilities may find it easier to integrate existing facilities into EMSs, by possibly utilizing new developments in digital technology. In this study, the impacts of both measures of financial ability are left as an empirical issue.

[4] We also note another view suggested by a referee: financially constrained firms lack adequate internal funds and hence must turn to the capital markets to finance their business activities. Thus, these firms may be more sensitive to investor pressures to develop EMSs.

(4) *Parent company's influence*

A firm's management and operations can be influenced by a parent company that owns a substantial amount of the firm's voting stock. The decision to develop an EMS is thus also likely to be influenced by the parent company. The parent company may believe that its reputation is affected by the environmental performances of its subsidiaries. Furthermore, the subsidiary firms may find it easier to develop EMSs because they may be able to use the experience and technical knowledge of the parent company. Thus, we hypothesize that if a firm has a parent company that has a highly developed EMS, the subsidiary firm will also have a highly developed EMS. No previous studies have empirically tested this hypothesis.

(5) *Market conditions*

EMSs can be viewed as cost-reducing product innovations (Spence, 1984) that provide more environmental services at a given cost, or as process innovations (Arrow, 1962). For both views, however, the theoretical and empirical literature makes ambiguous predictions about the role of market conditions in affecting innovation. Early work (Schumpeter, 1942) argues that greater market power and concentrated market structure favor innovation because concentrated market structures reduce uncertainty associated with rival behavior, and firms with greater market power are better able to appropriate the returns from innovation. Later extensions, however, demonstrate that theoretical predictions depend on the type of innovation and the nature of product market competition, among other things (Aghion, Harris, Howitt, & Vickers, 2001; Aghion, Bloom, Blundell, Griffith, & Howitt, 2002; Ahn, 2002; Van Cayseele, 1998). Arrow (1962) demonstrates that for a process innovation, competitive market provides stronger incentives to innovate than a monopolistic market. However, subsequent theoretical extensions obtain mixed or contrasting results (Bester & Petrakis, 1993; Bonanno & Haworth, 1998; Qiu, 1997; Symeonidis, 2003).

Despite many empirical studies, the estimated effects of market conditions on innovation are not robust (Aghion et al., 2002, Blundell, Griffiths, & van Reenen, 1999; Cohen & Levin, 1989; Cohen, 1995; Geroski, 1995; Nickell, 1996). Given the mixed theoretical and empirical results described above, we leave the direction of the impact of market conditions as an empirical matter.

2.2 Measures and definitions

The following variables are used to represent the factors that are hypothesized to affect the development of EMSs: advertising expenditures, capital intensity, foreign ownership, industry average emissions, current debt ratio, age of assets, R&D expenditures, parent company's quality of EMSs, market share, and the Herfindahl–Hirschman index. In addition, we include as additional control variables the export ratio and an interaction term of advertising expenditures and industry average emissions. The variables and their definitions are summarized in Table 1.

Table 1 List of variables and definitions

Variable	Definition
Advertising expenditures (billion yen)	Annual expenditures on advertisement
Capital intensity	Fixed assets divided by number of employee
Foreign ownership (%)	Percentage of shares owned by foreign investors
Industry average emissions (1,000 tons)	Average total emissions of PRTR chemicals per firm in each industry
Current debt ratio	Current liabilities divided by total assets
Age of assets	Total assets divided by gross assets
R&D expenditures (billion yen)	Annual expenditures on research and development
Top 10	= 1 if a firm has a parent company whose quality of EMS is in top 10; = 0 otherwise
Top 11-25	= 1 if a firm has a parent company whose quality of EMS is in top 11-25; = 0 otherwise
Market share (%)	Firm's sales divided by total industry sales
Herfindahl–Hirschman index	Sum of squared market share of firms in the industry
Export ratio (%)	Ratio of export sales to the total sales

Stakeholder pressures are represented by advertising expenditures, capital intensity, and foreign ownership. Although firms may differ in their motivations for setting advertising expenditure levels, firms are likely to be well known among consumers if they have large advertising expenditures. Thus, advertising expenditures can be considered as a measure of proximity to consumers. Firms with greater advertising expenditures are likely to have stronger contact with consumers and therefore these firms may have stronger incentives to develop comprehensive EMSs in order to publicize their environmental activities and attract consumers who have preferences for environmentally-friendly firms.[5] Similar to Khanna and Anton (2002) and Anton, Deltas, & Khanna (2004), we use capital intensity as a measure of reliance on capital markets and thus a proxy for pressures from general investors. Capital intensity is defined as the value of fixed assets per employee. The ratio of foreign ownership is constructed as the percentage of stocks held by foreign owners.

We use industry average emissions to represent industry-wide regulatory pressures. Industry average emissions are constructed as the average total emissions of the chemicals per firm in each industry reported in Japan's Pollutant Release and Transfer Register (PRTR). Like the Toxics Release Inventory (TRI) of the United States, Japan's PRTR is an inventory of currently unregulated, but potentially toxic, chemicals.[6] Firms operating in industries with

[5] Among past studies, Nakamura, Takahashi, & Vertinsky (2001) used advertising expenditures per sales as a measure of consumer goodwill. Khanna and Anton (2002) used a dummy variable indicating whether firms are mainly producing final goods or intermediate goods. Since many Japanese firms diversify their product mix and produce both final and intermediate goods, using such a dummy variable in our analysis is not enlightening.

[6] The distinction between currently *regulated* and currently *unregulated* chemicals may be important. Large emissions of currently *regulated* chemicals may indicate lax regulations that allow them to stay dirty. We thank a referee for bringing up this to our attention.

large PRTR emissions may perceive stronger pressures from the threat of more stringent future regulations. Furthermore, Decker (2003, 2004) found that facilities with larger TRI emissions receive more frequent regulatory inspections and experience longer waiting times for obtaining environmental permits. Thus, firms in industries with large PRTR emissions may be operating under stronger regulatory pressures and thus industry average emissions can be considered as a weak proxy for regulatory pressures. However, we acknowledge that industry average emissions may not be a strong proxy for regulatory pressures.

Technical ability is measured by R&D expenditures. Firms with higher R&D expenditures are likely to have a higher stock of technical knowledge. Financial ability is measured by current debt ratio and age of assets. Current debt ratio is defined as current liabilities divided by total assets. It measures short-term financial flexibility. Age of assets, which is a measure of costs of replacing existing facilities, is defined as total assets divided by gross assets, where gross assets are defined as total assets plus accumulated depreciation on tangible fixed assets. A higher value indicates newer facilities.

The influence of a parent company on EMS comprehensiveness is represented by dummy variables “Top 10” and “Top 11-25.” These variables indicate that the parent company is ranked among the top 10 or top 11-25 firms in terms of EMS comprehensiveness (see Sect. 3.1 for our measure of comprehensiveness of EMSs).

We include two measures of market conditions, market power of each firm within a given industry and a degree of concentration of each industry. Market power is approximated by market share, which is calculated as dividing sales of a firm by total industry sales. Larger market share indicates larger market power for a given industry.[7] Degree of market concentration is measured by the Herfindahl-Hirschman index. The index is calculated for each industry as the sum of squared market share (measured in %) of each firm in the industry. Thus, the index takes values between 0 and 10,000, where the maximum is attained when the industry is characterized by monopoly.

In addition to the above variables that are hypothesized to affect the development of EMSs, we include two control variables: the export ratio and an interaction term of consumer pressures and regulatory pressures. There is anecdotal evidence that Japanese firms take proactive environmental actions to penetrate EU and North American markets, which typically have stringent environmental requirements (for example, see (Roht-Arriaza, 1997)). Firms with higher export ratios are more likely to respond to such pressures. The export ratio may also reflect pressures from consumers in foreign countries. Since the export ratio was found to be important in ISO 14001 adoption among Japanese firms (Nakamura et al., 2001), we include it as a control variable. Export ratio is defined as the ratio of export sales to total sales.[8] We also include an interaction

[7] Strictly speaking, the Lerner Index is the theoretically valid measure of market power. In practice, however, market share is widely used, including in antitrust cases, because obtaining the necessary data to calculate the Lerner Index is difficult (Goldberg & Knetter, 1999).

[8] We did not find export data by regions (Europe, North America, etc.).

term to investigate whether the effectiveness of consumer pressures depends on the degree of regulatory pressures.[9]

For all variables constructed at the industry-level, we use the industry classification of the Japan Company Handbook (Toyo Keizai, 1999, 2002) (approximately same as two-digit SIC codes in the U.S.).

3 Data and empirical methods

3.1 Dependent variable

This section describes how the dependent variable, which represents comprehensiveness of firms' EMSs, is constructed. We use data from the Fifth Environmental Survey of Japanese Manufacturers conducted by the Nikkei Newspaper.[10] The questionnaires were sent to a total of 2,040 firms, consisting of all manufacturing firms listed in the Tokyo Stock Exchange and a small number of other manufacturing firms in September (2001). The response rate was 40.2% (820 firms). The questionnaires had approximately 50 main questions, plus associated sub-questions. These questions covered eight aspects of environmental management practices that firms employ, such as degree of disclosure of environmental information about the firm, degree of establishment of monitoring and audit systems of pollutants that are generated through production processes, extent of employee training, comprehensiveness of firm's recycling practices, and so on. After the questionnaires were collected, the answers were summed for each practice, producing what the Nikkei Newspaper called a "score" for each environmental practice by individual firms. Since the numbers of associated questions were slightly different across practices, the Nikkei Newspaper standardized the scores so that the mean becomes 50 and the standard deviation becomes 10. Our data consists of standardized scores of each of the eight environmental practices at the individual firm level. The description of these eight practices is summarized in Table 2.

To construct a valid measure of EMS comprehensiveness, one must address two issues. First, many management practices can constitute an EMS, and thus a measure of EMS comprehensiveness must be based on sufficiently many management practices. Second, a comprehensiveness measure should reflect variation across firms in the intensity with which firms engage in the same environmental management practices. For example, two firms may have training programs for employees, but they can differ in how extensively training is provided (whether only managers receive training or all employees receive training), how frequently opportunities for training are provided, and whether employee sanctions and rewards depend on environmental management

[9] We thank a referee for this suggestion.

[10] The Nikkei Newspaper is Japan's equivalent of the Wall Street Journal. Although the Nikkei Newspaper has the copyright of the survey results, the survey itself was designed and conducted in cooperation with Nikkei Research. Nikkei Research is a well-known research institute in Japan specializing in corporate research, marketing research, and database development.

Table 2 Summary of eight categories of environmental management practices

Variable name	Description
ISO 14001	Degree of introduction of management systems related to ISO 14000 series
Information disclosure	Degree of environmental information disclosed and ease of access to the disclosed information by the public
Employee training	Extent of employee training and environmental consideration in human resource management (such as whether there are incentive programs to promote environmental awareness among employees)
Long-term plans	Whether firms have various long-term environmental management plans
Risk management	Risk management of potentially harmful chemicals
Recycling	Comprehensiveness of recycling practices
Resource and energy use monitoring	Degree of monitoring of resource use, energy use, and green-house gas emissions in production processes
Life-cycle assessment	Comprehensiveness of life cycle assessment, or assessment of environmental impacts of firm's products at various stages of their production and consumption

Note: This table is constructed based on Nihon Keizai Shimbun (2002)

performance. These two issues are addressed in our dataset: The survey covers sufficiently many aspects of a firm's EMS (eight environmental practices) and measures intensity for each of the environmental practices through additional questions associated with each of the practices. Thus, we base our analyses on a reasonable measure of the comprehensiveness of EMSs.

As an objective measure of the comprehensiveness of the EMS for each firm, we use the principal component score that is obtained from applying a principal component analysis (PCA) to the dataset.[11] Principal component analysis is a commonly used statistical technique used to reduce the dimensionality of possibly correlated variables without losing much of the information contained in the original data set. Mathematically, PCA determines the optimal weights w_{ik} for linear combinations of the p original variables $\mathbf{v_j}$'s ($j = 1, 2, \ldots, p$). In our dataset, $\mathbf{v_j}$'s correspond to scores for the eight environmental practices and $p = 8$. As is standard, we normalized $\mathbf{v_j}$ such that the mean becomes 0 and the standard deviation becomes 1, and then applied PCA in order to produce robust results.

The results of PCA are shown in Table 3.[12] The eigenvalue associated with the kth principal component represents the proportion of the variance of the original variables explained by the kth principal component. The proportion of the variance explained, labeled as contribution ratio, is calculated as each

11 The Nikkei Newspaper also applied PCA and a portion of the results were published in a report (Nihon Keizai Shimbun, 2002). We conducted PCA by ourselves to investigate the validity of the measure of comprehensiveness in details. Although the dependent variable is based on the results of PCA conducted by ourselves, similar figures (the first principal component scores) are available in Nihon Keizai Shimbun (2002).

12 The first two principal components are also shown in Nihon Keizai Shimbun (2002). Although there are slight differences, our results are consistent with their results.

Table 3 Results of principal component analysis

Variables	First principal component	Second principal component	Third principal component
ISO 14001	0.361	0.111	−0.412
Information disclosure	0.358	0.283	−0.391
Employee training	0.338	0.385	0.746
Long-term plans	0.358	0.018	0.031
Risk management	0.361	−0.401	−0.112
Recycling	0.344	−0.537	0.314
Resource and energy use monitoring	0.362	−0.303	−0.063
Life-cycle assessment	0.346	0.468	−0.056
Eigenvalue	6.267	0.392	0.328
Contribution ratio (%)[a]	78.33	4.90	4.09

Note: [a] Contribution ratio represents the proportion of the variance explained, and is calculated as each eigenvalue divided by 8

eigenvalue divided by 8 (mathematically the sum of all eight eigenvalues must equal to 8). As is shown, the first principal component explains over 78% of the variance, while the second principal component explains only 4.9%. Thus, the first principal component captures most of the information contained in the original 8 variables and thus can reasonably be considered as a measure of the comprehensiveness of firms' EMSs. Let S_i be the degree of the comprehensiveness of the ith firm's EMS as measured by the first principal component score. A larger value indicates more comprehensive EMSs. We treat S_i as a continuous variable because it takes sufficiently many values.[13]

3.2 Estimation methods

In this section, we explain the empirical methods used to evaluate the determinants of the comprehensiveness of EMSs developed by firms. In the previous section, we hypothesized that the comprehensiveness of a firm's EMS is determined by firm characteristics. This relationship is represented by

$$S_i = \mathbf{X_i}\beta + u_i, \tag{1}$$

where $\mathbf{X_i}$ is a vector of variables that are hypothesized to affect EMS comprehensiveness, and u_i is an error term. Some of the firm characteristics might be endogenously (contemporaneously) affected by the comprehensiveness of EMS. In order to avoid endogeneity, firm characteristics are measured with a three-year lag. Thus, a vector of firm characteristics $\mathbf{X_i}$ is measured in 1998.

[13] Principal component scores take different values for each firm. For all 820 firms that responded, the score ranges from −3.79 to 6.73, with median −0.39. The score is not truncated from below because all firms have at least some environmental practices and therefore we do not use a Tobit model.

The dependent variable is constructed from survey results, and thus is observed only for those firms that responded to the survey. This raises an econometric issue in the estimation of Eq. (1) because the non-response may be based on self-selection rather than random sampling. A firm's decision to respond to the survey may depend on the firm's expected score. For example, firms with less comprehensive EMSs may be less likely to respond to the survey because a low score can lead to bad publicity or simply because managers at such firms are uninterested in responding to an environmental questionnaire.[14] Thus, the estimation of Eq. (1) by the ordinary least squares (OLS) may lead to biased coefficient estimates. Although self-selection by non-response is always an issue in surveys, controlling for it in the analysis is difficult because independent variables associated with non-respondents are not often available. In our dataset, we know to whom surveys were sent (all manufacturing firms listed in the Tokyo Stock Exchange) and the firm characteristics data are available from published data sources for both respondents and non-respondents.

By taking advantage of this feature, we address the self-selection problem using full information maximum likelihood estimation (FIML). FIML produces an asymptotically efficient estimator. Let D_i be a binary variable representing whether or not a firm has responded to the survey, where $D_i = 1$ if a firm has responded and $D_i = 0$ if it has not responded. Therefore, S_i is observed only when $D_i = 1$. Firms are assumed to respond to the survey only if doing so will give them higher profits. In order to model the decision to respond to the survey, we introduce a latent variable D_i^*. D_i^* represents the ith firm's incentive to respond to the survey such that $D_i = 1$ if $D_i^* \geq 0$ and $D_i = 0$ if $D_i^* < 0$. We model the decision as

$$D_i^* = \mathbf{Z_i}\gamma + v_i. \tag{2}$$

The vector $\mathbf{Z_i}$ contains all the variables in $\mathbf{X_i}$ (measured in 1998) because the decision to respond is likely to depend on the expected score S_i, which in turn is hypothesized to be affected by $\mathbf{X_i}$. $\mathbf{Z_i}$ also contains sales measured in 2001, which is not in $\mathbf{X_i}$. This variable serves as an exclusion restriction, although the model is identified through assumptions on the error terms even without such a restriction. As will be shown later in regression results, the response rate is significantly positively correlated with sales.

We make a standard assumption that u_i and v_i are jointly normally distributed with mean zero and covariance matrix $\begin{pmatrix} \sigma^2 & \rho\sigma \\ \rho\sigma & 1 \end{pmatrix}$. $\mathrm{Var}(v_i)$ is normalized to be 1 for identification purpose because we observe only the sign of D_i^*. Both Eqs. (1) and (2) are simultaneously estimated using full information maximum likelihood estimation (FIML). The log-likelihood function to be maximized is given by Davidson and MacKinnon (1993)

[14] Firms do not need to know the exact scores they would receive in order for this conjecture to be plausible. Firms only need to know whether their EMSs are generally comprehensive or not.

$$\sum_{D_i=0} \log(\Phi(-\mathbf{Z_i}\gamma)) + \sum_{D_i=1} \log\left(\frac{1}{\sigma}\phi((S_i - \mathbf{X_i}\beta)/\sigma)\right)$$
$$+ \sum_{D_i=1} \log\left(\Phi\left(\frac{\mathbf{Z_i}\gamma + \rho((S_i - \mathbf{X_i}\beta)/\sigma)}{\sqrt{1-\rho^2}}\right)\right), \quad (3)$$

where ϕ and Φ are the density and the cdf of the standard normal distribution respectively.

We note the possibility that the observations may be correlated within each industry due to industry specific effects. In one specification (Model 1 in Table 5), we solve this problem by including industry dummy variables. However, when industry dummy variables are included, we cannot recover other industry-level variables such as the Herfindahl–Hirschman index and industry average emissions. Therefore, in other specifications (Models 2, 3, and 4 in Table 5), we use standard errors corrected for clustering at the industry level (Rogers, 1993), which is an extension of robust standard errors by Huber (1967) and White (1980). With clustering, Eq. (3) becomes the pseudo-likelihood function because the joint probability density for the entire sample is no longer the product of the probability density functions for each observation. Partial maximum likelihood (PML) estimation method computes the maximum of Eq. (3) and provides a consistent estimate of the parameters. This is a special case of the more general quasi-maximum likelihood estimation that provides consistent estimator with a misspecified likelihood (Wooldridge 2002, Sect. 13.8).

3.3 Data

The independent variables, X_i and Z_i, are taken from published data books. All firm characteristics are taken from the *Japan Company Handbook* with the following exceptions. Advertising expenditures are taken from *Ad Spending of Leading Japanese Corporations*. Age of assets is calculated using data on accumulated depreciation from *Nikkei Annual Corporation Reports*. The industry average emissions are constructed based Japan's PRTR data.[15]

The initial sample consisted of the 2,040 firms to which the questionnaires were sent. Of these, we excluded firms not listed in the Tokyo Stock Exchange because data on these firms are very limited. This first exclusion resulted in 1,575 firms. After selecting only the firms with complete data, we had a sample size of 1,154.[16] We used these 1,154 firms to estimate Eq. (1) and (2). Of these 1,154 firms, 536 firms responded to the survey and therefore have principal component scores.

[15] The variables are constructed based on emissions data during 2001 because prior years are not available (Japan's PRTR started in 2001). We thus implicitly assume that industry pollution intensities do not change over a short period.

[16] We thus implicitly focus only on the listed firms. Focusing on listed firms is consistent with previous studies (e.g., Khanna & Anton, 2002; Nakamura et al., 2001) and thus facilitates comparisons with extant empirical work. We do not observe any systematic patterns by which firms are dropped.

Table 4 Descriptive statistics

Variable	All firms	Respondents	Non-respondents
Principal component score		0.360 (2.410)	
Advertising expenditures (billion yen)	1.453 (5.452)[a]	2.695 (7.667)	0.376 (1.441)
Capital intensity	0.032 (0.049)	0.033 (0.027)	0.031 (0.061)
Foreign ownership (%)	5.064 (7.829)	7.46 (9.30)	2.98 (5.49)
Industry average emissions	88.47 (99.45)	87.03 (99.96)	89.71 (99.06)
Current debt ratio	0.392 (0.185)	0.371 (0.171)	0.411 (0.195)
Age of assets	0.746 (0.130)	0.736 (0.127)	0.754 (0.133)
R&D expenditures (billion yen)	7.22 (33.69)	14.47 (48.41)	0.94 (2.08)
Top 10	0.022 (0.146)	0.041 (0.199)	0.0049 (0.070)
Top 11-25	0.025 (0.157)	0.028 (0.165)	0.023 (0.149)
Market share (%)	1.14 (2.58)	1.94 (3.53)	0.449(0.792)
Herfindahl–Hirschman index	526.63 (307.39)	527.45 (323.09)	525.92 (293.34)
Export ratio (%)	13.34 (18.29)	16.45 (19.47)	10.64 (16.76)
Sales (billion yen, 2001)	221.94 (770.94)	418.65(1,097.08)	51.34 (65.43)
N	1,154	536	618

Note: All variables are measured in 1998 unless specified
[a] Standard deviations are shown in parentheses

Table 4 shows descriptive statistics for all firms (all 1,154 firms used for the estimation of Eqs. (1) and (2)), for firms that responded to the survey, and for firms that did not respond to the survey. For some variables, the means of respondents and non-respondents differ substantially. For example, the mean R&D expenditures for respondents and non-respondents are 14.47 and 0.94 billion yen respectively. Similarly, the mean advertising expenditures and sales for respondents are much larger than those for non-respondents. Such differences suggest that self-selection may exist due to both observable and unobservable factors.

4 Results and discussion

4.1 Results

This section presents regression results and discusses their policy implications. In order to examine the robustness of the results, we estimate five different specifications. Table 5 presents the results. Model 1 includes industry dummy variables, which capture industry-specific effects that may exist. Since other variables measured at the industry level cause multicollinearity, they are dropped. Model 2 replaces the separate industry intercepts with a common intercept and adds the variables that are dropped from Model 1. In order to correct for possible clustering at the industry level, we apply PML estimation method with robust standard errors corrected for clustering. Model 2 also excludes the interaction term of consumer pressures (advertising expenditures) and regulatory pressures (industry average emissions). Model 3 adds the interaction term to Model 2. These two models can examine the robustness of the results to the interaction term. Throughout the first three models, current debt ratio was found to be consistently insignificant in the equation of interest (Eq. (1)) but highly significant in the selection equation (Eq. (2)). Thus, current debt ratio is likely to be a valid exclusion restriction. In Model 4, current debt ratio is dropped from Eq. (1) to serve as an additional exclusion. Model 4 examines if this additional exclusion affects the results of the first three models. Model 5 uses OLS with the same specification as Model 3 to examine if the estimates are sensitive to self-selection. It also uses robust standard errors corrected for clustering.

Models 1–4 all reject the null hypothesis that $\rho = 0$ at the 1% level, indicating that self-selection is statistically significant. Estimates of the selection equation indicate that firms' decision to respond to the survey is significantly positively correlated with sales. We can see how self-selection affects estimates in Table 5. Generally speaking, the OLS estimates tend to be larger in magnitude and statistically more significant. For example, the coefficient on the Herfindahl–Hirschman index is insignificant under Models 2, 3, and 4, but is strongly significant under OLS. The magnitude of the coefficient under OLS is approximately three times that under other models. Similarly, foreign ownership is significant under OLS, but becomes either insignificant (Models 3 and 4) or weakly significant (Models 1 and 2) after controlling for self-selection. For all statistically significant coefficients, the OLS estimates are larger in magnitude with the exception of R&D expenditures and industry average emissions. The effect of industry average emissions (regulatory pressures) is insignificant under OLS but is significant under all other models after controlling for self-selection. Furthermore, the magnitude is more than twice that under OLS.

The regression results are robust across specifications that control for self-selection. Both magnitude and statistical significance are similar for Models 1–4. Nonetheless, there are a few differences. In Model 1, R&D expenditures are insignificant and export ratio is only weakly significant, whereas both variables are strongly significant under other models. This may indicate that both R&D expenditures and export ratio include significant industry-specific effects and that these two variables indirectly affect development of EMSs mainly through their industry-specific effects. By comparing Models 2 and 3, we see that the coefficient estimates of all statistically significant variables are insensitive to the absence or presence of the interaction term except advertising expenditures and industry average emissions. Both of these variables have smaller coefficients without the interaction term (this makes sense because the interaction term is significantly negative). By comparing Models 3 and 4, we can see that the estimates are insensitive to the additional exclusion restriction.

Table 5 Determinants of comprehensiveness of EMSs

Independent variables	Model 1[a] (FIML with industry dummies)	Model 2 (PML without interaction term)	Model 3 (PML with interaction term)	Model 4 (PML with additional exclusion)	Model 5 (OLS)
Constant	2.377 (0.818)***	2.143 (0.924)**	1.793 (0.896)*	1.682 (0.877)*	1.947 (0.968)*
1. Stakeholder pressures					
Advertising expenditures	0.0982 (0.0263)***	0.0314 (0.0228)	0.0878 (0.0206)***	0.0900 (0.0191)***	0.116 (0.0220)***
Capital intensity	1.150 (3.505)	−0.0797 (3.881)	−1.829 (3.515)	−1.848 (3.550)	−0.232 (3.899)
Foreign ownership	0.0194 (0.0106)*	0.0206 (0.0111)*	0.0186 (0.0118)	0.0202 (0.0126)	0.0391 (0.0139)**
2. Regulatory pressures					
Industry average emissions		0.00582 (0.00287)**	0.00736 (0.00303)**	0.00773 (0.00264)***	0.00272 (0.00319)
Industry average emissions squared		−9.58E-06 (8.14E-06)	−0.0000114 (8.22E-06)	−0.0000126 (7.08E-06)*	3.30E-06 (8.08E-06)
3. Ability					
Current debt ratio	−0.130 (0.547)	−0.492 (0.518)	−0.309 (0.567)		−0.341 (0.748)
Age of assets	−1.661 (0.865)*	−2.067 (0.996)**	−1.965 (0.939)**	−2.022 (0.906)**	−3.457 (0.884)***
R&D expenditures	0.00274 (0.00280)	0.00563 (0.00256)**	0.00481 (0.00116)***	0.00469 (0.00114)***	0.00452 (0.00159)**
4. Parent company's influence					
Top 10	1.706 (0.466)***	1.866 (0.391)***	1.907 (0.372)***	1.905 (0.378)***	2.541 (0.484)***
Top 11-25	0.938 (0.487)*	1.031 (0.419)**	1.015 (0.421)**	1.030 (0.438)**	1.109 (0.343)***
5. Market conditions					
Market share	0.105 (0.0351)***	0.0820 (0.0332)**	0.0926 (0.0346)***	0.0908 (0.0349)***	0.178 (0.0467)***
Herfindahl–Hirschman index		−0.000372 (0.000449)	−0.000371 (0.000403)	−0.00035 (0.000414)	−0.00117 (0.00028)***
6. Other control variables					
Export ratio	0.00945 (0.00516)*	0.0133 (0.00319)***	0.0160 (0.00342)***	0.0163 (0.00332)***	0.0233 (0.00347)***
Advertising expenditures × Industry average emissions	−0.000266 (0.000086)***		−0.000257 (0.000062)***	−0.000261 (0.000059)***	−0.000369 (0.000078)***

Table 5 continued

Independent variables	Model 1[a] (FIML with industry dummies)	Model 2 (PML without interaction term)	Model 3 (PML with interaction term)	Model 4 (PML with additional exclusion)	Model 5 (OLS)
Selection equation (equation 2)					
Constant	−0.0823 (0.400)	0.116 (0.383)	−0.0267 (0.388)	−0.00181 (0.415)	
Advertising expenditures	0.0493 (0.0436)	−0.0187 (0.0388)	0.0342 (0.0693)	0.0347 (0.0689)	
Capital intensity	−1.415 (1.644)	−1.913 (1.394)	−1.900 (1.410)	−1.908 (1.420)	
Foreign ownership	−0.00169 (0.00685)	−0.000506 (0.00650)	−0.000345 (0.00671)	−0.000737 (0.00650)	
Industry average emissions		0.000113 (0.00251)	0.000830 (0.00247)	0.000766 (0.00247)	
Industry average emissions squared		−4.34E-06 (7.37E-06)	−5.91E-06 (7.41E-06)	−5.69E-06 (7.34E-06)	
Current debt ratio	−0.590 (0.266)**	−0.585 (0.158)***	−0.576 (0.168)***	−0.638 (0.190)***	
Age of assets	−0.910 (0.434)**	−0.911 (0.360)**	−0.765 (0.354)**	−0.755 (0.344)**	
R&D expenditures	0.0716 (0.0214)***	0.0886 (0.0334)***	0.0959 (0.0323)***	0.0961 (0.0324)***	
Top 10	0.523 (0.331)	0.617 (0.211)***	0.617 (0.218)***	0.615 (0.219)***	
Top 11-25	0.0381 (0.267)	0.0461 (0.217)	0.0346 (0.222)	0.0331 (0.224)	
Market share	0.0891 (0.0722)	0.0366 (0.0806)	0.0459 (0.084)	0.0465 (0.0832)	
Herfindahl–Hirschman index		0.000108 (0.000208)	0.000105 (0.000208)	0.000098 (0.000208)	
Export ratio	−0.00301 (0.00278)	0.000318 (0.00308)	0.000171 (0.00313)	0.000129 (0.00315)	
Advertising expenditures × Industry average emissions	−0.000606 (0.000259)**		−0.000511 (0.000351)	−0.000516 (0.000348)	
Sales	0.00534 (0.000837)***	0.00510 (0.00107)***	0.00485 (0.00108)***	0.00484 (0.00107)***	

Table 5 continued

Independent variables	Model 1[a] (FIML with industry dummies)	Model 2 (PML without interaction term)	Model 3 (PML with interaction term)	Model 4 (PML with additional exclusion)	Model 5 (OLS)
Number of observations	Respondents = 536 Non-respondents = 618	Respondents = 536 Non-respondents = 618	Respondents = 536 Non-respondents = 618	Respondents = 536 Non-respondents = 618	536
ρ (standard error) {P-value}[b]	−0.816 (0.030) {0.000}	−0.807 (0.036) {0.000}	−0.785 (0.041) {0.000}	−0.785 (0.041) {0.000}	
R^2					0.431
Log pseudo-likelihood		−1627.4	−1619.9	−1620.1	
Log likelihood	−1587.8				

Note: The dependent variable is the first principal component score. Standard errors are shown in parentheses
*** Statistically significant at the 1% level
** Statistically significant at the 5% level
* Statistically significant at the 10% level
[a] Industry dummies are suppressed. They are jointly significant at the 1% significance level
[b] ρ is the correlation coefficient between u_i and v_i. P-value shown in curly brackets is the probability that $\rho = 0$

The hypothesis that stakeholder pressures affect development of comprehensive EMSs is partially supported. Advertising expenditures are strongly significant in all models except Model 2. Firms with larger advertising expenditures and thus in stronger contact with consumers are likely to develop more comprehensive EMSs. There is only weak evidence that investor pressures affect development of EMSs. High ratio of foreign shareholders is likely to positively affect development of comprehensive EMSs, but the effect is weak and not robust. There is little evidence that stronger pressures from the general investor population, as measured by larger capital intensity, lead to more comprehensive EMSs.

Regarding the hypothesis on regulatory pressures, we find that firms with large industry average emissions are more likely to develop comprehensive EMSs. We explained in Sect. 2.2 that industry average emissions can be considered as a weak proxy for regulatory pressures. Therefore, the fact that firms with large industry average emissions of PRTR chemicals are more likely to develop comprehensive EMSs may be interpreted as supportive evidence that regulatory pressures encourage EMS development. We would like to emphasize that this interpretation hinges on the presumption that industry average emissions are a proxy for regulatory pressures.

The effects of financial and technical abilities are partially significant. Financial constraints as measured by current debt ratio are not statistically significant in any specification. On the other hand, the costs of investment as measured by age of assets have a statistically significant effect. Firms with newer facilities, and thus with higher costs of replacing the existing facilities, have significantly less comprehensive EMSs. Concerning the effect of technical knowledge, we obtained a mixed result. R&D expenditures are strongly significant in Models 2–5, but are insignificant when industry dummy variables are added. As noted above, this may indicate that a significant portion of R&D expenditures includes industry-specific effects and that R&D expenditures affect development of EMSs mainly through their industry-specific effects.

The hypothesis that a parent company influences the comprehensiveness of the subsidiary company's EMS is strongly supported. Firms that have parent companies in the top 10 in terms of the comprehensiveness of EMSs are likely to develop more comprehensive EMSs. The coefficient of Top 11-25 is also positive and significant, but the magnitude is smaller than that of Top 10.

The effects of market conditions are mixed. Firms with larger market share and thus with larger market power have significantly more comprehensive EMSs. Firms with a larger Herfindahl–Hirschman index, implying they are operating in more concentrated industries, are significantly less likely to develop comprehensive EMSs only under OLS. After controlling for self-selection, the effect is not statistically significant.

Table 6 shows the determinants of intensity for each of the eight environmental practices. We used the Model 3 specification and applied PML estimation method with standard errors corrected for clustering. Generally speaking, variables that are significant for the comprehensiveness of EMSs tend to be significant for many of the environmental practices. No independent variables

Table 6 Determinants of intensity for each environmental management practice

Independent variable	ISO 14001	Information disclosure	Employee training	Long-term plans	Risk management	Recycling	Resource and energy use monitoring	Life-cycle assessment
Constant	0.507 (0.388)	0.493 (0.386)	−0.0416 (0.379)	0.694 (0.434)	1.086 (0.281)***	0.774 (0.386)**	1.351 (0.376)***	0.294 (0.446)
Advertising expenditures	0.0293 (0.00663)***	0.0336 (0.00827)***	0.00886 (0.0137)	0.0144 (0.00731)**	0.0326 (0.00943)***	0.0301 (0.00618)***	0.0401 (0.0106)***	0.0428 (0.0105)***
Capital intensity	−1.708 (1.469)	1.499 (1.508)	0.863 (1.618)	0.180 (1.748)	−1.305 (1.176)	−2.129 (1.521)	−1.785 (1.807)	−1.583 (1.701)
Foreign ownership	0.00558 (0.00362)	0.00428 (0.00398)	0.00206 (0.00267)	0.0110 (0.00451)**	0.00655 (0.00695)	−0.000621 (0.00515)	0.0111 (0.00589)*	0.00220 (0.00530)
Industry average emissions	0.00250 (0.00129)*	0.00181 (0.00103)*	0.00123 (0.00104)	0.00227 (0.00180)	0.00530 (0.00142)***	0.00403 (0.00125)***	0.00261 (0.00167)	0.00205 (0.00131)
Industry average emissions Squared	−4.64E-06 (3.73E-06)	−2.20E-06 (2.84E-06)	9.20E-07 (3.03E-06)	−1.24E-06 (5.13E-06)	−0.0000128 (4.07E-06)***	−7.04E-06 (3.58E-06)**	−5.77E-06 (4.49E-06)	−2.23E-06 (4.26E-06)
Current debt ratio	−0.229 (0.227)	0.242 (0.168)	0.170 (0.255)	0.281 (0.268)	−0.289 (0.179)	−0.226 (0.252)	−0.269 (0.214)	−0.428 (0.289)
Age of assets	−0.379 (0.448)	−0.549 (0.426)	0.206 (0.419)	−0.803 (0.477)*	−1.346 (0.351)***	−0.678 (0.404)*	−1.596 (0.278)***	0.188 (0.494)
R&D expenditures	0.00203 (0.000478)***	0.00144 (0.000642)**	0.00392 (0.000901)***	0.00169 (0.00067)**	0.000188 (0.000643)	0.00147 (0.000431)***	0.00205 (0.000427)***	0.00127 (0.000609)**
Top 10	0.742 (0.133)***	0.731 (0.0717)***	0.720 (0.156)***	0.360 (0.168)**	0.883 (0.113)***	0.470 (0.152)***	0.672 (0.216)***	0.442 (0.333)
Top 11-25	0.537 (0.171)***	0.241 (0.142)*	0.570 (0.389)	0.303 (0.200)	0.314 (0.171)*	0.119 (0.255)	0.184 (0.185)	0.430 (0.133)***
Market share	0.0293 (0.0161)*	0.0469 (0.0161)***	−0.00111 (0.0152)	0.0451 (0.0135)***	0.0198 (0.0122)	0.0322 (0.00854)***	0.0133 (0.0139)	0.0321 (0.0139)**
Herfindahl–Hirschman index	−0.0000597 (0.000186)	−0.000262 (0.00014)*	0.0000813 (0.00021)	−0.000332 (0.000156)**	2.18E-06 (0.000154)	−0.000126 (0.000149)	−0.0000624 (0.000215)	−0.0000558 (0.000168)

Table 6 continued

Independent variable	ISO 14001	Information disclosure	Employee training	Long-term plans	Risk management	Recycling	Resource and energy use monitoring	Life-cycle assessment
Export ratio	0.00567	0.00522	0.00399	0.00506	0.00883	0.00628	0.00764	−0.00005
	(0.00146)***	(0.00139)***	(0.00172)**	(0.00206)**	(0.00205)***	(0.00139)***	(0.00186)***	(0.00126)
Advertising expenditures × Industry average emissions	−0.0000936	−0.000097	−0.0000282	−0.0000604	−0.0000907	−0.0000856	−0.000111	−0.000105
	(0.000019)***	(0.000022)***	(0.000032)	(0.000014)***	(0.000030)***	(0.000018)***	(0.000035)***	(0.000025)***
Log pseudo-likelihood	−1191.1	−1163.3	−1211.8	−1197.6	−1168.8	−1208.2	−1161.6	−1207.3

Note: *** Statistically significant at the 1% level
** Statistically significant at the 5% level
* Statistically significant at the 10% level

are consistently significant for all environmental practices, but there are variables that are significant for most (seven out of eight) of the environmental practices. These include advertising expenditures, R&D expenditures, top 10 (parent company's influence), export ratio, and the interaction term of advertising expenditures and industry average emissions. Some of the variables such as industry average emissions, age of assets, and market share are significant only for selected environmental practices. For example, age of assets appears to affect only long-term plans, risk management, recycling, and resource and energy use monitoring. This result makes sense. Development of the latter three practices tends to require new investment into facilities. Therefore, firms with older facilities will tend to have higher intensities for these environmental practices.

4.2 Comparisons with previous studies

Our broad findings generally support previous findings (Anton et al., 2004; Dasgupta et al., 2000; Henriques & Sadorsky, 1996; Khanna & Anton, 2002; Nakamura et al., 2001; Welch et al., 2002). For example, these studies generally found that stakeholder pressures and regulatory pressures are important drivers (Dasgupta et al., 2000; Henriques & Sadorsky, 1996; Khanna & Anton, 2002). However, there are several important differences.

First, previous studies on firm adoption of environmental practices (Anton et al., 2004; Dasgupta et al., 2000; Henriques & Sadorsky, 1996; Khanna & Anton, 2002; Nakamura et al., 2001; Welch et al., 2002) used survey data but did not control for self-selection. We found that after controlling for self-selection, the effects of industry average emissions tend to become larger in magnitude and statistically more significant while the effects of other variables tend to become smaller in magnitude and less significant. Since industry average emissions can be considered as a weak proxy for regulatory pressures, our results may be interpreted as supportive evidence that controlling for self-selection reinforces the importance of regulatory pressures.

Second, our results suggest that the factors that motivate EMS comprehensiveness by Japanese firms may not be exactly the same as those motivating firms in the U.S. and Canada. Whereas studies in the U.S. and Canada (Henriques & Sadorsky, 1996; Khanna & Anton, 2002) found that pressures from general shareholders are important in motivating firms to take proactive actions, we were unable to detect such effects. We did, however, find weak evidence that firms that receive stronger pressures from foreign investors are likely to develop more comprehensive EMSs. This result might indicate that domestic investors are not as concerned with the environmental activities of firms as foreign investors are. We also found that the effect of R&D expenditures is mixed and the effect of the Herfindahl–Hirschman index becomes insignificant when self-selection is controlled for. Khanna and Anton (2002) found both of these factors statistically significant in firm adoption of environmental practices in the United States, but our results do not support their findings. We cannot conclude whether these findings are due to the methodological differences (self-selection) or the true differences in the behaviors of Japanese firms and firms in other countries, but our results indicate more careful studies are needed in order to accurately quantify the relative importance of various motivations.

Third, there are some important differences between our results and those of previous studies on Japanese firms. For example, Nakamura, Takahashi, & Vertinsky (2001) found that R&D expenditures negatively affect adoption of ISO 14001 among Japanese firms. In contrast, we found the effect of R&D expenditures is positive, although the significance of the variable is not robust across different specifications. In addition, consumer pressures were found to explain only some aspects of ISO 14001 adoption among Japanese firms (Nakamura et al., 2001; Welch et al., 2002), but our results suggest that Japanese firms do receive strong pressures from consumers to be environmentally proactive. Furthermore, contrary to Nakamura, Takahashi, & Vertinsky (2001), we found financial health does not affect EMS development.

4.3 Policy implications

In order to assess policy implications of the results, we examine how comprehensiveness of firms' EMSs changes when firm characteristics are changed. Table 7 calculates the changes in the principal component score (our dependent variable) when the independent variables that are statistically significant under Model 3 are changed for two standard deviations. The result is shown in the column labeled "Changes in predicted score".[17] We can see that regulatory pressures as measured by industry average emissions has the largest impact, and consumer pressures as measured by advertising expenditures has the second largest impact. In the far right column, we calculate how changes in the predicted principal component score translate into changes in the relative position of the firms' comprehensiveness of EMSs. These figures are derived by first adding the predicted change in the principal component score to the principal component score at the median (50th percentile) and then finding the percentile that corresponds to this score. A change in the percentile is then calculated by subtracting 50 from this percentile. Thus, these figures represent changes in the relative position from the median when one of the independent variables is changed for two standard deviations holding others fixed at their means. As can be seen, changes in percentiles are generally large. Regulatory pressures have a potential to change the comprehensiveness of a firm's EMS by more than 16%. These observations have several policy implications.

First, since industry average emissions can be considered as a weak proxy for regulatory pressures, our findings can be interpreted as evidence that the government directly affects the comprehensiveness of EMSs despite the oft-claimed

[17] For advertising expenditures and industry average emissions, effects through the interaction term are also added. Since the interaction term is negative, the changes in predicted score are smaller than the values calculated by ignoring the effects through the interaction term.

Table 7 Economic significance of independent variables

Variable	Coefficients	Standard deviation of the variable	Changes in predicted score[a]	Changes in percentiles[b]
Advertising expenditures	0.0878	5.452	0.709	9.51
Industry average emissions	0.00736	99.45	1.390	16.46
Age of assets	−1.965	0.130	−0.511	7.80
R&D expenditures	0.00481	33.69	0.324	5.37
Top 10	1.907	0.146	0.557	8.17
Top 11-25	1.015	0.157	0.319	5.24
Market share	0.0926	2.58	0.478	7.44
Export ratio	0.0160	18.29	0.585	8.41

Note: [a] Changes in predicted principal component score are calculated by changing each variable for two standard deviations holding other variables fixed at their means. For advertising expenditures and industry average emissions, effects through the interaction term are also added

[b] Changes in percentiles are derived by first adding the predicted change in the principal component score to the principal component score at the median (50th percentile) and then finding the percentile that corresponds to this score. A change in the percentile is then calculated by subtracting 50 from this percentile

"voluntary" nature of EMS development. Furthermore, as shown in Table 7, this direct regulatory effect may be large. However, we would like to add a caveat that this interpretation hinges on the presumption that industry average emissions are a proxy for regulatory pressures.

Second, regulators can use these empirical results to target future incentive programs aimed at encouraging EMS development. We identified firm characteristics that are likely to significantly affect the comprehensiveness of EMSs. Lack of these characteristics may deter firms' development of EMSs. Therefore, policy makers can target firms that lack these characteristics and provide assistance through incentive programs. For example, public recognition seems an effective tool since consumer pressures has the second largest impact. A subsidy on EMS-related investment may work as well since the replacement costs of existing facilities as measured by age of assets were found significant. Although we have a mixed result on the effect of R&D expenditures, technical assistance may turn out to be an effective incentive. The results we derived in Table 7 suggest that if regulators can affect these incentives through appropriately designed public programs, such programs may create reasonably large changes in the comprehensiveness of firms' EMSs.

Third, the negative coefficient of the interaction term implies that consumer pressures are less effective in inducing firms to further develop EMSs when firms are operating in industries with large average emissions. For example, when industry average emissions are at the mean, increasing advertising expenditures by two standard deviations will increase predicted score by 0.709 as in Table 7. This value will fall to 0.431 when industry average emissions are at one standard deviation above the mean, and will further fall to 0.152 when industry average emissions are at two standard deviations above the mean. There are two possible interpretations of this result. If average industry emissions are a proxy for regulatory pressures as we claimed, then one interpretation is that consumer pressures are less effective when firms already receive strong regulatory pressures. An alternative interpretation is based on the presumption that industry average emissions actually measures lax regulatory pressures. Under this scenario, consumer pressures are less effective when firms are large polluters because dirty industries have captured regulators, which enables them to stay dirty. Our data do not allow us to draw a definitive conclusion, but given that industry average emissions can be considered as a weak proxy for regulatory pressures, the first conclusion seems a more natural interpretation.

5 Conclusions

In this study, we investigated the factors that motivate firms to develop comprehensive EMSs. We found that industry average emissions (a proxy for regulatory pressures) have the largest impact and advertising expenditures (a proxy for consumer pressures) have the second largest impact in inducing firms to develop comprehensive EMSs. Our findings generally support previous analyses (Anton et al., 2004; Dasgupta et al., 2000; Henriques & Sadorsky, 1996; Khanna & Anton, 2002; Nakamura et al., 2001; Welch et al., 2002). However, we found that after controlling for self-selection in survey responses, the effects of these factors tend to become smaller in magnitude and statistically less significant except regulatory pressures.

We believe our results are important not because we found a few results that differ from previous analyses (such as the effects of market conditions, technical knowledge, and financial health), but because our results support the broad findings of the previous analyses even after controlling for self-selection using a different dataset. This consistency provides an important foundation for turning academic research into effective policies.

We found that regulatory pressures as measured by industry average emissions have the largest effect and that the magnitude of consumer pressures is affected by the level of regulatory pressures firms receive. Although we cannot draw a definitive conclusion because industry average emissions may not be a strong proxy for regulatory pressures, these findings can be viewed as providing supportive evidence that the government directly affects the comprehensiveness of EMSs. In addition, the government can potentially affect firms' EMS development indirectly through appropriately designed public incentive programs. Therefore, despite the oft-claimed "voluntary" nature of EMS development, the government may have a role to play in both directly and indirectly affecting EMS development. However, the effectiveness of more comprehensive EMSs in improving firm's environmental performances remains poorly understood. Future research needs to clarify the magnitude of changes in environmental performances that arise from the development of more comprehensive EMSs.

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