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Environmental Policy and Corporate Behaviour

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Preface

Recent work in the OECD and elsewhere has highlighted the importance of an understanding of the firm's commercial motivations, decision-making procedures, and organizational structure when governments are designing and implementing public environmental policies. In order to cast light on these issues this book provides a summary of the outputs from a three-year project – 'Environmental Policy and Firm-Level Management' – involving the collection and analysis of data from over 4000 manufacturing facilities in seven OECD countries (Japan, France, Germany, Hungary, Norway, Canada and the United States).

The project was overseen by the OECD Environment Directorate, in collaboration with researchers from the seven countries involved. In addition, valuable inputs into project design were provided by the members of an advisory group made up of officials from participating country governments. The full list of researchers and advisory group members is given in Appendix 1. And finally, valuable critiques of the work were provided by academics, government officials, business representatives and others at a conference supported by the Environmental Protection Agency and Environment Canada, held in Washington DC in June 2005.

The project leader, Nick Johnstone, would like to express his sincere gratitude to all, and most particularly to the participating researchers. A project of this kind depends upon the understanding, patience and flexibility of all concerned and no project leader could have asked for more from his collaborators in this regard, nor anticipated the richness of the learning experience which arose out of this collaboration.

And finally, the financial support of the Ministry of Environment Japan, Hungarian Ministry of Environment, French Ministry of Ecology and Sustainable Development, French Environment and Energy Management Agency, German Federal Ministry of Education and Research, Norwegian Ministry of the Environment, Environment Canada, Industry Canada and the United States Environmental Protection Agency is gratefully acknowledged.

1. Public environmental policy and corporate behaviour: project background, overview of the data and summary results

Nick Johnstone, Céline Serravalle, Pascale Scapecchi and Julien Labonne

I. INTRODUCTION

Much of the economic analysis of environmental policy can be summarized under two principles: (1) many aspects of the natural environment are public goods, and as such private economic agents will not behave in a manner which is consistent with social welfare maximization in the absence of public intervention; and (2) the use of market-based instruments is a more economically efficient means of achieving a given environmental objective since they encourage an efficient allocation of resources and effort and provide stronger dynamic incentives for environmentally beneficial technological innovation.

However, the treatment of the inner workings of the firm is largely absent from the vast body of literature in support of these two principles. Nonetheless, recent work (DeCanio 1998; Gabel and Sinclair-Desgagné 2001) has highlighted the importance of an understanding of the firm's commercial motivations, decision-making procedures and organizational structure when designing and implementing public environmental policies. Issues such as the allocation of responsibilities for environmental matters within the firm, the use of different accounting and investment appraisal procedures, the implementation of environmental management systems, and other managerial responses are likely to affect how firms respond to different environmental policy measures. As Stiglitz (1991) has pointed out, 'most production in modern economies occurs within organisations, and this production is regulated only to a limited extent by prices . . . These observations make it clear that if economists wish to understand how resources in modern economies are allocated, we must understand what goes on inside organisations.'

Such issues are not usually reflected in discussions of the design of the environmental policy framework and the relative merits of different environmental policy instruments. Indeed, assessments of the different public environmental policy measures often treat the internal workings of the firm as a 'black box', assuming that firms will respond in a predictable manner. Given this shortcoming, the OECD's Working Party on National Environmental Policies provided support for the initiation of an industrial survey exploring the links between public (government) environmental policies and private (firm and facility) environmental management, investments, innovation and performance (www.oecd.org/env/cpe/firms).

Perhaps most importantly, the effects of environmental policy stringency, enforcement mechanisms and instrument choice on environmental performance remains imperfectly understood. In addition, there is good evidence that apparently similar firms appear to exhibit wide variation in their performance, and this can not be fully explained by public policy factors. Amongst other factors the role of internal management structures on environmental performance has received increasing attention, but the role that environmental management systems (certified or not), environmental management tools (environmental accounting, training, auditing, reporting, and so on) and delegation of managerial responsibility have on environmental performance has not been subject to systematic analysis.

This is significant since environmental management has become the target of important government policy initiatives, with public authorities assuming that more comprehensive environmental management encourages improved environmental performance. However, it is not clear what policy incentives are effective in encouraging the introduction of environmental management practices which have a distinct and causal role in bringing about improved environmental performance. This is an area in which there is much policy experimentation, and empirical evidence is much needed.

One of the key determinants of improved environmental performance in the long run is clearly technological innovation. Through investments in environmental research and development firms can identify innovative means of addressing pressing environmental problems. However, the costs incurred can be considerable. Clearly, policy stringency – by changing relative prices or introducing production constraints – will induce innovation of some kind. However, instrument choice may also play a role. If firms are to search for innovative solutions through investment in R&D their returns are likely to be greater if more flexible policy instruments are implemented rather than prescriptive measures, allowing for broader potential application of any innovations discovered. In addition, the implementation of advanced environmental management practices may both lower the potential costs of R&D and increase its benefits.

However, R&D is an input measure of innovation. While data on the technological characteristics of different types of innovation is scarce, one possible output measure of innovation is the propensity to invest in changes in production processes (CPP) rather than end-of-pipe abatement. The former allows for the integration of abatement and other environmental decisions with more general production practices, and thus may allow for the realization of economies of scope. To the extent that more prescriptive policy measures (such as technology-based regulations) may constrain the realization of such economies of scope, more flexible measures such as performance standards and economic instruments are thought to be preferable. In addition, the location of the individual within the facility who is designated as being responsible for environmental matters may be significant, since investment in CPP has far-reaching implications for the firm's overall production strategy and investment decisions.

The choice between end-of-pipe solutions and changes in production processes raises the issue of environmental–commercial synergies. It is often argued that good environmental performers are good commercial performers. There is little question that through costs savings, product differentiation, firm branding, and so on, proactive environmental performance can result in commercial benefits. However, while this may be true, it is less clear that this has significant public policy implications. Thus, it is important to evaluate the extent to which public environmental policy can induce commercial gains, and conditions under which this may be the case.

In this volume an assessment of the effects of environmental policy and other factors on environmental management, performance and innovation is provided. It does so by summarizing empirical results based upon a database of over 4000 manufacturing facilities in seven OECD countries. The data was collected by participating research teams[1] in Canada, the United States, France, Germany, Norway, Hungary and Japan in early 2003 by means of a postal survey.[2] Empirical analysis was undertaken in the following broad areas:

- the determinants of having in place an environmental management system or tools (Chapter 2);
- the determinants of undertaking various investments to reduce environmental impacts (Chapter 3);
- the determinants of investing in environment-related research and development (Chapter 4);
- the determinants of improving environmental performance through changes in production processes rather than end-of-pipe abatement (Chapter 5); and,

- the links between commercial strategies and performance and environmental actions (Chapter 6).

In each case, the objective has been to provide practical advice concerning the effectiveness and efficiency of alternative environmental policy measures and the implications for public policy are set out in Chapter 7. These can be summarized as follows:

- Stringency of the perceived public policy regime (and to a lesser extent inspection frequency) is generally the most significant influence on environmental performance, as well as technological innovation.
- Instrument choice is less significant as a determinant of performance, but more flexible instruments appear to play a role in encouraging investment in environment-related research and development and cleaner production (as opposed to end-of-pipe solutions).
- Environmental management systems, tools and practices have a distinct causal role in encouraging improved performance, but the results indicate that if such systems are to be actively encouraged the policy incentives should be chosen with care.
- There may be environment–commercial 'win–wins' in a general sense, but the evidence indicates that such opportunities are not induced by public policy measures.

It must be recognized that these results are based upon analyses undertaken on a single cross-section at a single point in time, rather than a longitudinal database across several periods. This poses limitations. In addition, there is potential for selection bias in the choice of respondents and strategic bias in the answers given. And finally, due to the nature of the survey instrument many of the variables are qualitative in nature, in many cases gauging perceptions rather than hard facts. However, despite these limitations – which are discussed where relevant in the chapters which follow – the data and the analyses provide a unique and rigorous body of evidence on the issues addressed.

II. OVERVIEW OF THE COVERAGE OF THE DATABASE

In total, the database includes approximately 4200 observations from facilities with more than 50 employees in all manufacturing sectors. Respondents were CEOs and environmental managers. Response rates range from

Table 1.1 Response rate by country

	Response rate (%)
Canada	25.0
France	9.3
Germany	18.0
Hungary	30.5
Japan	31.5
Norway	34.7
United States	12.1
Total	24.7

approximately 9 per cent to 35 per cent, with a weighted mean of almost 25 per cent (see Table 1.1). For a postal survey this is satisfactory, particularly since previous industrial surveys undertaken in the environmental sphere in many of the countries included in the survey have tended to have very low response rates. While surveys undertaken as part of official data-collection exercises may have higher response rates, in many such cases there are legal obligations to respond. Other studies also focus on large firms (for example *Standard and Poor's 500*) or firms with other attributes (that is, listed on the stock exchange) which are likely to have higher response rates. Indeed, given the population sampled, the response rate was higher than had been anticipated.[3]

Table 1.2 provides data on the number of respondent facilities by industrial sector for the seven countries. While the sectoral data is available at the International Standard Industrial Classification (ISIC) two-digit level (24 sectors), the data is presented in somewhat aggregated form below.

The transport equipment, machinery equipment, and non-metallic mineral product sectors are particularly well represented. At the other end, the pulp and paper and printing and publishing sectors, and the basic metal sectors have relatively few respondents. This is generally consistent with the distribution of the population of facilities, and a comparison of the distribution of the sample and the population at the sectoral level can be found at www.oecd.org/env/cpe/firms.

Most significantly, there are a large number of observations from smaller facilities for which response rates are usually much lower (see Table 1.3). Indeed, in many studies small and medium-sized enterprises are not sampled at all – a significant shortcoming as regulators increasingly seek to influence the behaviour of smaller sources of pollution. In the sample, well over 2500 facilities can be characterized as small or medium-sized enterprises (SMEs) (< 250 employees). Given that many of these same facilities

Table 1.2 Survey respondents by sector and by country

	ISIC Classification	Canada	France	Germany	Hungary	Japan	Norway	USA	Total
Food, beverage and tobacco	Sectors 15–16	23	44	77	68	138	33	37	420
Textiles, apparel, leather	Sectors 17–19	8	13	40	50	72	10	12	205
Wood products and furniture	Sectors 20 and 36	32	12	26	27	32	49	34	212
Paper, publishing & printing	Sectors 21–22	22	17	92	21	129	25	24	330
Fuel, chemicals, rubber, plastics	Sectors 23–25	40	48	149	54	195	24	126	636
Non-metallic mineral products	Sector 26	13	13	34	21	34	14	20	149
Basic & fab'd metals	Sectors 27–28	42	53	211	52	286	54	129	827
Machinery and instruments	Sectors 29–33	50	47	227	119	439	55	59	996
Motor vehicles & transp. eqpmt	Sectors 34–35	23	19	32	22	113	44	37	290
Recycling and other	Sectors 37–39	3	2	10	29	29	1	5	79
Total		256	268	898	463	1467	309	483	4144

Table 1.3 Survey respondents by facility size (# of employees) and by country

	Canada	France	Germany	Hungary	Japan	Norway	USA	Total
50–99	76	85	351	66	661	155	96	1490
100–249	68	81	278	198	508	102	130	1365
250–499	62	39	130	101	178	36	130	676
>500	50	64	139	101	152	16	133	655
Total	256	269	898	466	1499	309	489	4186

Table 1.4 Percentage of respondents with various firm/facility characteristics

	Final good (%)	Listed on stock exchange (%)	International markets (%)	Positive profits (3-year avg) (%)	Foreign head office (%)
Canada	49.19	33.46	71.76	90.53	33.20
France	37.12	21.19	64.42	77.95	11.52
Germany	39.82	10.86	76.40	84.43	13.79
Hungary	46.00	9.87	61.40	83.45	23.38
Japan	31.48	10.18	19.23	75.91	1.95
Norway	42.86	13.82	52.61	78.15	19.22
United States	41.67	45.00	63.22	83.99	13.07

are part of multi-facility firms, the true representation of SMEs in the database at the level of the firm is somewhat lower, but still very significant. A comparison of the distribution of the sample and the population by facility size can be found at http://www.oecd.org/env/cpe/firms.

Table 1.4 gives mean values of different facility or firm characteristics across countries. For instance, between 30 per cent and 50 per cent of facilities report that their main markets are either households or retailers and wholesalers. Few Hungarian, German and Japanese facilities (approximately 10 per cent) report that their firm is listed on the stock exchange. Conversely, in the United States and Canada the proportion is very high. Japanese respondents are much less likely to report that international markets are their primary market, and that their head office is overseas. In terms of profitability, over 90 per cent of facilities reported that they were in the black in Canada, with the averages for the other countries being somewhat lower. Appendix 1A of this chapter provides descriptive statistics for many of the variables used in the empirical analyses in the subsequent chapters.

III. ENVIRONMENTAL POLICY REGIME AND STAKEHOLDER INFLUENCES

In the questionnaire (www.oecd.org/env/cpe/firms) data were collected on the characteristics of the public environmental policy regime. Indeed, relative to other projects the database is particularly rich with respect to the characterization of the public environmental policy framework, although much of the information is qualitative in nature and based on the respondents' perceptions. For instance, the data on the public environmental policy regime include data on perceived stringency of the policy framework, number of inspections in the last three years, perceived relative importance of different policy instruments, and the reported presence of targeted measures to encourage the use of environmental management systems or tools. In addition, respondents were requested to report on their perception of the relative importance of a variety of non-governmental stakeholders in influencing environmental practices.

There is very wide variation in the perceived stringency of the environmental policy regime. For instance, while less than 5 per cent of facilities in Japan felt that the environmental policy regime was very stringent (and more than 65 per cent found it to be not particularly stringent), the figures for France and the United States are between 30 per cent and 40 per cent (Figure 1.1). These may not reflect the actual relative stringency of policy regimes prevailing in different countries, but give a good indication of the perception of their relative stringency. In many of the analyses undertaken, perceived policy stringency is the most important determinant of private environmental performance and innovation, which is to be expected, perhaps indicating absence of significant strategic bias amongst respondents. See, for instance, Chapter 3 (Johnstone et al.), Chapter 4 (Arimura et al.), and Chapter 5 (Frondel et al.).

In addition, figures on the mean number of times that facilities report having been inspected varies markedly by country (see Figure 1.2). For instance, half of all facilities in Japan report that they were not inspected in the last three years. This may be due to the greater stigma associated with inspections in Japan, indicating that the threat of inspection itself plays a greater deterrent role.[4] Overall, somewhat more than 5 per cent of facilities report having been inspected more than ten times in the last three years. The correlation between reported number of inspections and the degree of perceived stringency of the policy regime is only 0.3, indicating that the two variables provide quite different information. Those facilities that report having been inspected frequently are not necessarily the same as those who perceive the policy framework as being stringent.

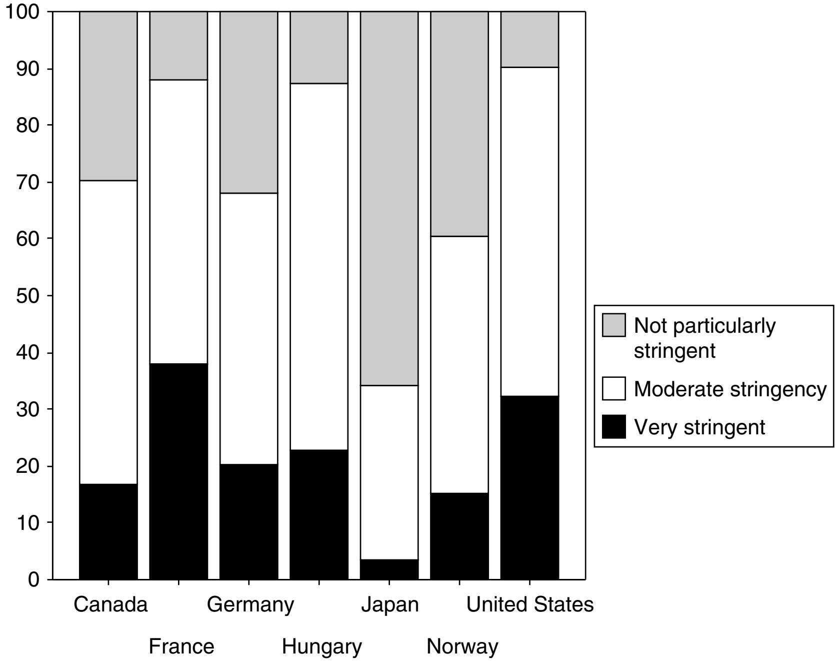

Figure 1.1 Perceived relative stringency of environmental policy regime

The nature of the environmental policy regime in terms of instrument choice also appears to differ by country. Facilities were requested to rate the influence of different environmental policy measures on their production activities on a scale from 1 to 3, with 0 indicating that the measure was 'not applicable'. Figure 1.3 indicates the mean response to some representative measures for those facilities which report that the measure was indeed present. At the descriptive level, Japanese facilities tend to report that the effects of different policies have less influence on their environmental practices. This is, of course, closely related to the responses on the 'degree of stringency'.

Comparing instrument type, all countries report that direct regulation and environmentally related taxes and charges are relatively important. However, there are some interesting subtleties. For instance, Japanese facilities are much less likely to report that technology-based regulations have a significant influence on their environmental practices. This is perhaps not due to their lack of widespread use but rather due to the perception that the policy regime is not particularly stringent and thus the regulations are not binding constraints on their behaviour. Subsidies or tax preferences

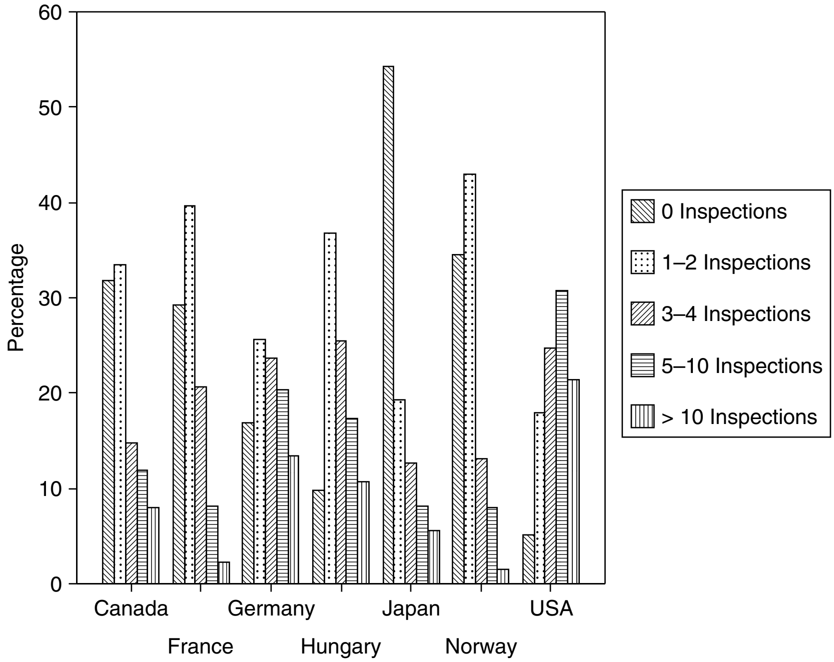

Figure 1.2 Reported frequency of inspections in last three years

and information-based measures are reported to be relatively more influential in Hungary than elsewhere.

With respect to the policy instrument variables it is important to emphasize that perception of the importance of an instrument may be influenced by the visibility and unpopularity of the instrument and the period in which it was introduced. For both of these reasons there may be a bias toward overestimating the importance of economic instruments, which are very visible, often controversial, and more recent in application. More significantly, respondents may be strategically biased, over-reporting the influence of measures which they feel are not in their private commercial interest relative to other instruments. Every effort has been made to address these potential concerns in the empirical analyses.

The role that different policy frameworks have on environmental management, innovation and performance has been explored using these responses as explanatory variables in the empirical studies undertaken on environmental performance, management and innovation (Chapter 3, Johnstone et al.; Chapter 2, Henriques and Sadorsky; Chapter 4, Arimura et al. and Chapter 5, Frondel et al.). For instance,

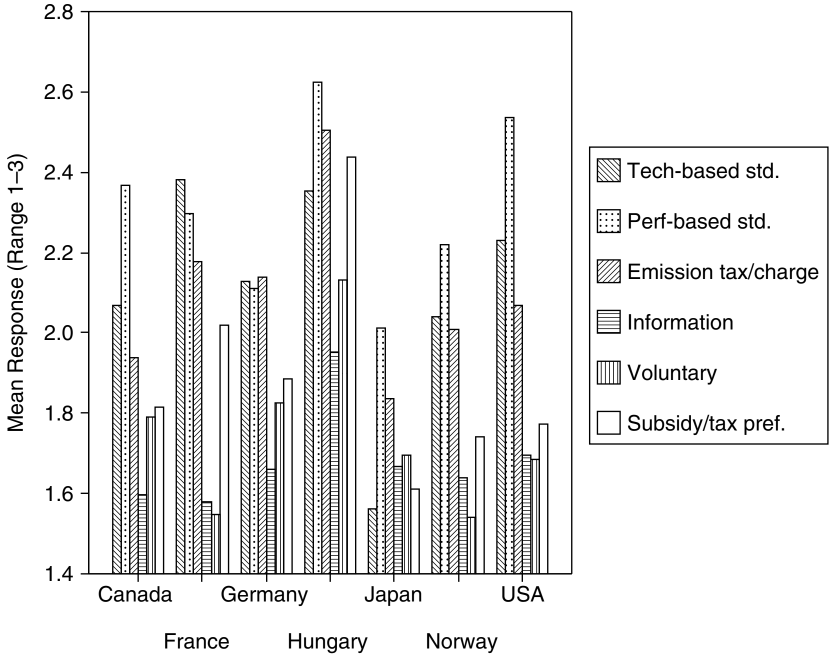

Figure 1.3 Perceived importance of different environmental policy instruments

the distinction between the use of flexible and prescriptive instruments is examined, as well as that between mandatory and voluntary policy measures. The results are not always consistent with a priori expectations, and some cases are discussed in sections IV and V below and in more detail in the later chapters.

Believing that environmental management can be a means of encouraging improved environmental performance, many governments also provide targeted support for the introduction of environmental management systems and tools (see Coglianese and Nash 2001 for a discussion). The OECD database provides a unique source of information with respect to these issues. Indeed, over 20 per cent of respondents reported that governments provided explicit incentives for the introduction of environmental management systems and tools. However, the figures vary widely. In the United States almost 40 per cent of facilities report such incentives, while in Germany the figure is less than 15 per cent. In Chapter 2, Henriques and Sadorsky find that such measures have a significant influence on the management decision.

The most common measure implemented is the provision of information with 65 per cent of respondent facilities reporting its presence. The provision of technical and financial assistance is common (over 40 per cent). Not surprisingly, the least common are waiving of regulations or reduced stringency of regulations. However, in both cases approximately 30 per cent of facilities report the presence of such incentives. The nature of the incentives provided varies significantly across countries. Some countries (for example France and Hungary) tend to favour the use of measures which reduce the cost of the implementation of environmental management systems and tools (technical assistance, financial assistance), while other countries (for example the United States) seek to increase the benefits from doing so (reduced inspection frequency, expedited permits, reduced regulatory stringency, public procurement preferences, and so on).

It is important to note that some facilities report the presence of particular incentives which are not formally in place in the country in question. However, even the perception of its presence can be significant if it influences the decisions made. Moreover, the nature of the incentive provided can have impacts which extend beyond the decision about whether or not to introduce environmental management systems (EMSs) and tools. For instance, some measures may encourage the use of EMSs as a signalling device (that is, public procurement preferences or special recognition). Still more problematic are cases in which the incentive has a direct effect on decisions related to environmental performance (that is, reduced regulatory stringency or frequency of inspections). The efficacy of such incentives is taken up in Chapter 3 by Johnstone et al.

Figure 1.4 reports on the reported influence of different stakeholders on facilities' environmental practices. This is also a subject of increased interest, with much work having been done on the role of financial markets (Ziegler et al. 2002; Khanna and Anton 2002; Cormier et al. 1993; Lanoie et al. 1998; Hamilton 1995). There has also been considerable work done on the role of community pressure, particularly in developing countries (Hartman et al. 1993; Pargal and Wheeler 1995; Arora and Cason 1996; Brooks and Seith 1997; Konar and Cohen 1997). In work undertaken separately by Johnstone and Scapecchi (2004) it was found that non-management employees played a significant role in bringing about improved environmental performance. The role of other stakeholders is much less amply assessed.

In terms of the descriptive data the most significant influences are public authorities and management employees. The latter were, of course, themselves the respondents. Recognizing that this may be important, the specific respondent within the facility was also requested to identify their position

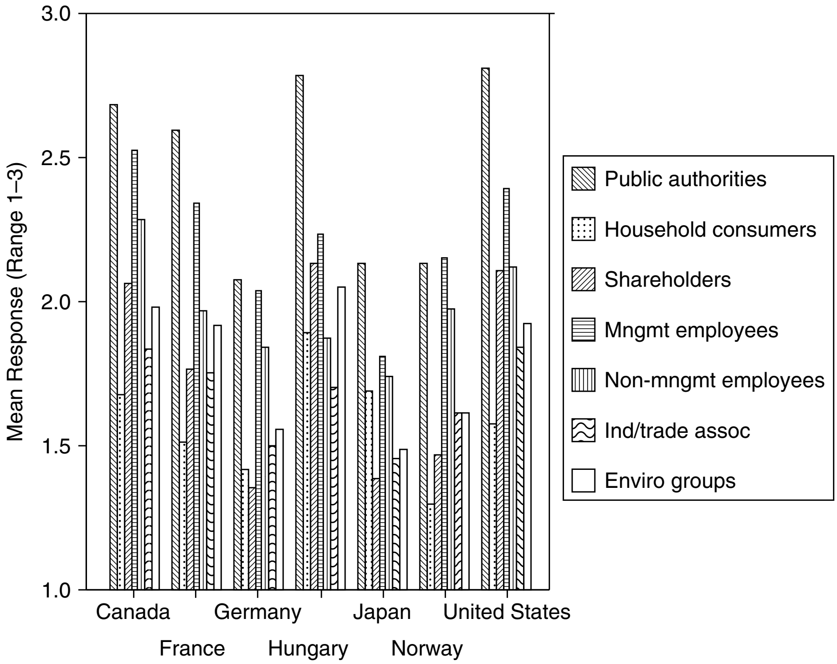

Figure 1.4 Reported influence of selected stakeholders on environmental practices

and institutional location within the facility. Consumers, industry and trade associations, and environmental NGOs all had limited influence. The role of environmental NGOs was greatest in Hungary. Overall, non-governmental shareholders appear to play a relatively important role in the United States and Hungary.

The role of such stakeholders is assessed in Chapter 2 by Henriques and Sadorsky in the work undertaken on the determinants of environmental management. It is found that the influence of environmental groups does not have a positive influence on the adoption of environmental management practices. Not surprisingly, corporate headquarters are the dominant stakeholder influence, with supply chain partners and workers also generally having a positive and significant influence on the decision to introduce such practices. In Chapter 5 Frondel et al. find that 'internal' stakeholders have a much greater influence on abatement decisions (whether change in production process or end-of-pipe abatement) than 'external' stakeholders such as unions and environmental NGOs.

IV. ENVIRONMENTAL MANAGEMENT SYSTEMS AND TOOLS

One of the primary objectives of the questionnaire was to collect information on the nature and extent of environmental management in different facilities. This relates not only to the presence of environmental management systems *per se* (certified and uncertified), but also to more specific environmental management tools, the institutional location of the person responsible for environmental matters, and general management practices which may have environmental implications. (For good discussions of the importance of an understanding of the internal workings of the firm when assessing environmental policy measures, see DeCanio 1998; DeCanio and Watkins 1998; and Gabel and Sinclair-Desgagné 2001.)

Overall, 37 per cent of respondents reported having an EMS. However, the number of facilities reporting that they had environmental management systems in place varies across countries, with figures ranging from just under 30 per cent of respondents (Germany and Hungary) to almost 45 per cent (United States) reporting that they have environmental management systems. However, there are large numbers of facilities reporting that they are in the process of implementing environmental management systems (see Figure 1.5).

Data on the number of facilities which have 'certified' environmental management systems was also collected, but this is not strictly comparable across countries since different schemes are relevant for different regions. Nonetheless, over 1000 facilities reported that they had ISO 14001 certification. In addition, data were collected for the year of certification. This information has been used to assess whether there are lags in the effect of EMSs on environmental performance in Chapter 3 (Johnstone et al.).

As expected, smaller facilities are less likely to have environmental management systems in place. Figure 1.6 gives the proportion of facilities with such systems for four different employee number classes. For the smallest class (50–99 employees) less than 20 per cent had an EMS, while for the largest class (>500 employees) the figure is over 60 per cent. The differences between the groups are statistically significant (even for the two higher classes), as indicated by the 95 per cent confidence intervals. In the work by Henriques and Sadorsky reported in Chapter 2, facility size does seem to have an important influence on the decision to introduce environmental management practices – perhaps reflecting administrative economies of scale. The geographical scope of the market is also important, with firms operating internationally more likely to introduce environmental management practices.

Since an EMS can mean very different things to different facilities in different countries, it is perhaps more interesting to examine facilities'

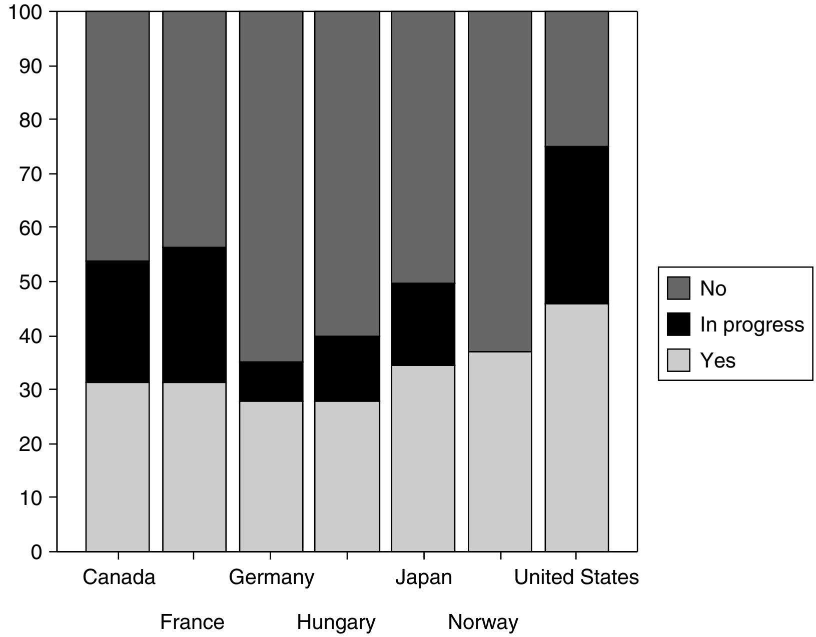

Figure 1.5 *Percentage of facilities with environmental management systems*

responses to questions concerning specific environmental management tools (Figure 1.7). The most commonly reported tools are written environmental policies and environmental training programmes. There is, however, variation across countries. In Germany, environmental accounting is much more important than elsewhere, and much more important than other tools. In the United States, there is a much greater tendency to use environmental training programmes. There are few facilities which evaluate or compensate employees on the basis of environmental criteria, except in the United States. Hungary and Norway have the greatest proportion of facilities with public environmental reports.

The organizational location of the individual who has overall responsibility for environmental matters varies widely across facility size class (see Table 1.5). Firstly, it is interesting to note that approximately 30 per cent of facilities did not report having anybody explicitly responsible for environmental matters. This ranges from a figure of over 45 per cent amongst facilities with less than 100 employees to just 6.6 per cent of facilities with more than 500 employees. Across countries the highest value is in Japan (over 40 per cent do not have such a person) with the lowest in the United States (<5 per cent).

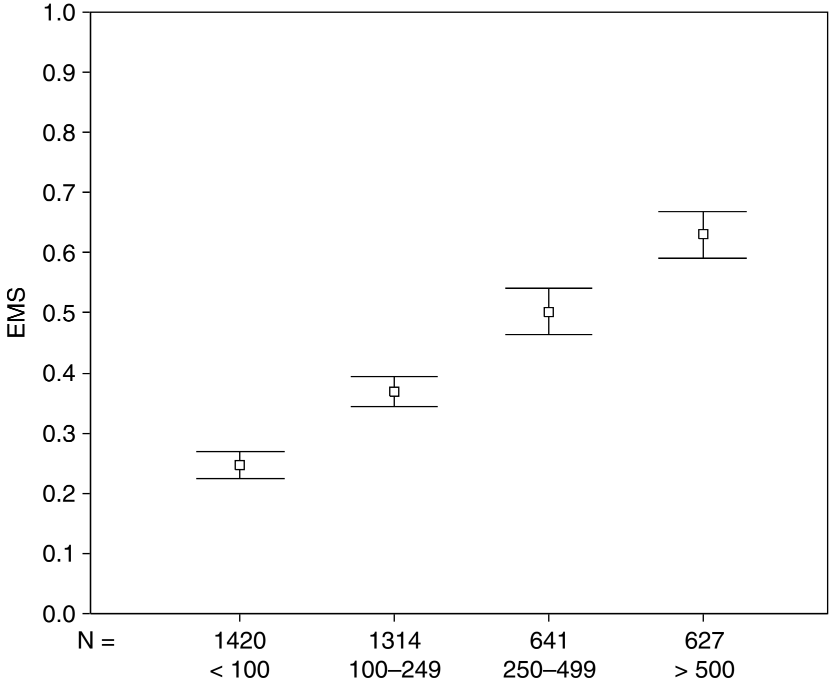

Figure 1.6 Relationship between facility size and presence (%) of environmental management systems

This may reflect differences in the extent to which responsibility for environmental matters is delegated formally or informally. Japan is a distinct outlier with respect to finance and accounting.

For those who reported having somebody explicitly responsible for environmental matters, in over 40 per cent of facilities in France responsibility rests with someone in an environmental health and safety (EH&S) department, compared with approximately 15 per cent in Norway and Japan (see Figure 1.8). Norway, Canada and Japan have the largest proportion of facilities for which the person responsible for environmental matters is characterized as being in senior management. Norway and the United States have the highest proportion defined as being in production or operations departments.

In addition, there appears to be a close relationship between the introduction of certain types of public environmental policy tools and the institutional location of the person responsible. Thus, it is found that the presence of economic instruments is correlated with having senior

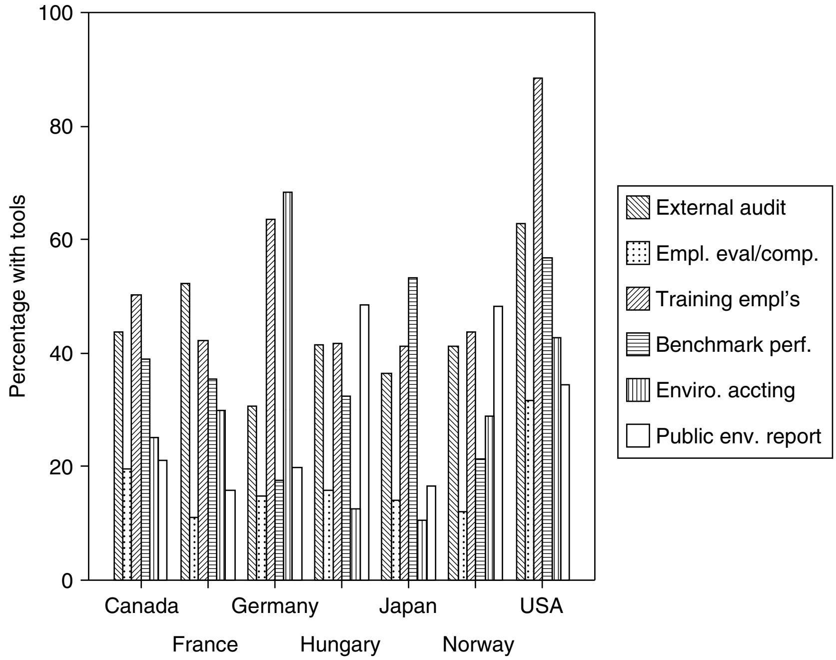

Figure 1.7 Proportion of facilities with selected environmental management tools

Table 1.5 Designated responsibility for environmental matters by facility size

	Employment class				
	<100	100–249	250–499	>500	Total
Somebody designated as being responsible	54.62%	68.01%	87.13%	93.40%	70.32%

management responsible for environmental matters, while direct regulations are more highly correlated with responsibility being vested with someone in a special EH&S (Environmental Health and Safety) department. As shown in work undertaken elsewhere this can have important indirect consequences. For instance, there may be indirect effects of policy choice on the propensity to undertake changes in production processes rather than end-of-pipe investment through the effects on institutional

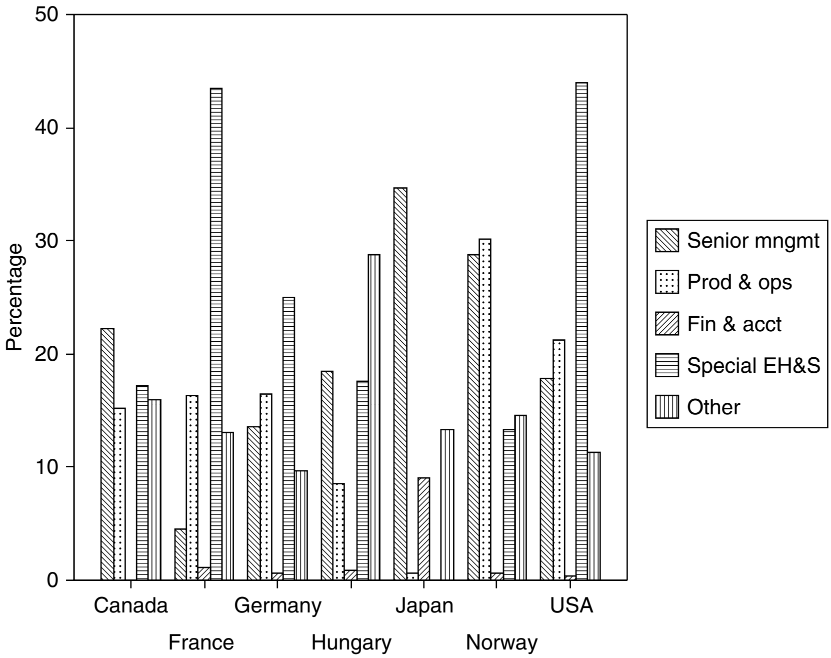

Figure 1.8 Institutional locus of responsibility for environmental matters

locus of responsibility. Somebody in a finance and accounting position with command over capital is much more likely to be in a position to bring about far-reaching changes in production processes (see Labonne and Johnstone 2006 for a discussion).

Facilities were also requested to indicate the extent to which they had introduced different 'advanced management practices' (that is, full-cost accounting, total quality management, and so on), and the extent to which these were integrated with environmental management (see Table 1.6). The inclusion of these variables allows for an assessment of the 'value added' provided by environmental management relative to other management practices (that is, does environmental accounting contribute to improved environmental performance in different areas beyond the contribution arising from the application of full-cost accounting?). Formal empirical work on the links between environmental management and general management practices has not yet been undertaken, but could be a valuable area for future research.

Different factors encourage or discourage a facility from introducing an EMS. Past research in this area includes articles by Henriques and

Table 1.6 Relationship between environmental management and general management

	% Yes	Degree of integration (Scale from 1 = not integrated, to 3 = fully integrated)
Quality management system	75	2.15
Health and safety management	60	2.14
Full-cost accounting	39	1.51
Management accounting	56	1.62
Process/job control system	48	1.67
Inventory/materials requirement planning	54	1.69

Sadorsky (1996); Khanna and Anton (2002); and Dasgupta et al. (2000). Multivariate analysis reported in Chapter 2 by Henriques and Sadorsky confirms that facility size has a positive effect on the probability of having implemented an EMS. In addition, facilities whose markets are more international in nature are more likely to have an EMS. The presence of a quality management system has a positive influence, reflecting perhaps economies of scope between the introduction of the two management systems. They also find that important influences for the decision to designate somebody as responsible for environmental matters are market scope (international), facility employment, business performance, the presence of a quality management system, and the influence of some stakeholders on environmental practices (for example workers and corporate headquarters).

As noted above, in the analysis undertaken by Henriques and Sadorsky the provision of targeted public incentives has a positive effect on the introduction of environmental management systems and tools. However, it does not increase the likelihood of having a certified EMS. In terms of specific policy incentives, even though they are not the most prevalent, econometric evidence reported in Chapter 3 by Johnstone et al. has indicated that only two factors are important in encouraging the introduction of environmental management systems: perceived reduction in the frequency of inspections, and the provision of public financial support. The former is particularly interesting since this can have negative consequences for actual environmental performance – encouraging strategic behaviour on the part of the worst environmental performers.

In Chapter 2 Henriques and Sadorsky report that inspection frequency has a positive role on the decision to designate somebody as being responsible for environmental matters. Interestingly, they also find that the provision of technical assistance as a general environmental policy tool (and not specifically to support the introduction of an EMS), has a negative influence on the introduction of environmental management systems and tools, as well as the designation of an individual as being responsible for environmental matters. On the basis of this result it would appear, therefore, that such assistance substitutes for, and does not complement, private initiatives. In addition, those respondents who feel that their production practices potentially have significant impacts on natural resource use are more likely to implement environmental management practices.

V. PREVALENCE AND NATURE OF ENVIRONMENTAL MEASURES UNDERTAKEN

Respondents were requested to indicate the change (if any) in their environmental performance in the last three years, whether they had undertaken significant environment-related investments, and if so the nature of such investments, and whether they had environment-related research and development programmes. Data collected from a survey on environmental performance and environmental initiatives are, of course, likely to reflect some bias (response and strategic). However, comparison of responses to the relevant questions with other data sources reveals reasonable degrees of correlation. (Corroboration of the Canadian data with a survey undertaken by Statistics Canada for a similar sample of facilities is available at www.oecd.org/env/cpe/firms.)

As noted, respondents were requested to report on whether in the last three years they had undertaken significant concrete actions to reduce environmental impacts in a number of different areas (that is, solid waste, local air pollution, wastewater, global air pollutants, environmental accidents, soil contamination, and so on). In general, there is surprising congruence across the countries with solid waste always the highest-reported impact (approximately 80 per cent) for which concrete actions have been taken, with over 85 per cent of Norwegian and American facilities reporting that significant efforts had been made. Wastewater is often second in importance, and global pollutants the lowest (between 20 per cent and 40 per cent). Actions taken to reduce the risk of severe accidents exhibits the greatest variance, with less than 50 per cent of Japanese facilities undertaking significant actions and almost 90 per cent in the American sample.

Reassuringly there is a high degree of correlation between facilities which report having undertaken concrete measures in those areas for which they feel that the potential negative environmental impacts from their

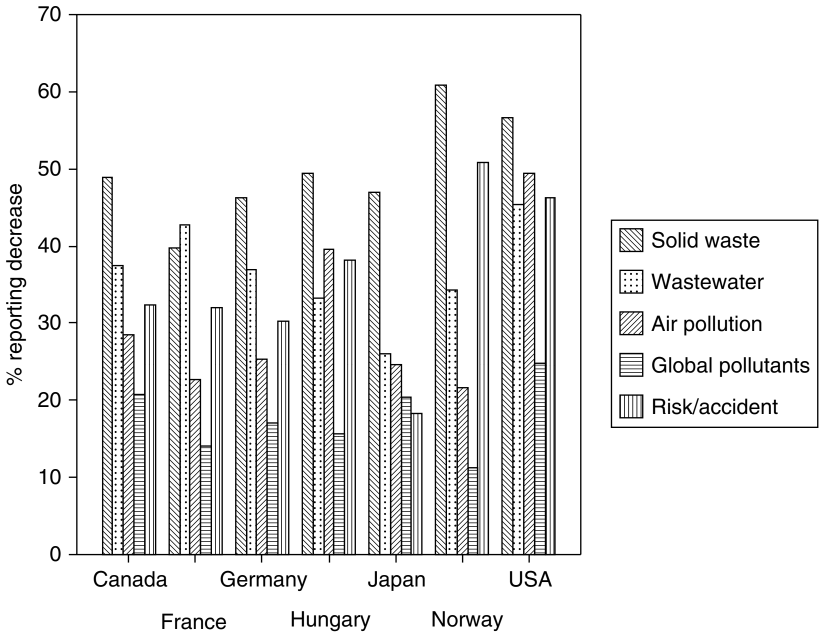

Figure 1.9 Reported environmental performance in last three years by type of environmental impact

production processes are likely to be significant. There are statistically significant positive correlations in all environmental impact areas.

Reported actions do not necessarily result in improved performance. As such, facilities were also requested to report on the change in environmental impacts from their activities in the last three years, ranging from significant decrease (1) to significant increase (5). For the same impact areas it is interesting to see that in all cases (except solid waste in Norway) less than 60 per cent of facilities represented a significant or moderate decrease. Solid waste represented the largest improvements followed by wastewater and air pollution, with global pollutants lagging far behind (see Figure 1.9).

As noted above, there has long been an interest in assessing the role of the public policy framework on environmental investments and performance. However, surprisingly little empirical work has been done in this area, perhaps because there is not sufficient variation in policy variables within individual countries, and significant (and measurable) changes in policy regimes are relatively infrequent across time. One notable exception is the work which has been done on the role of inspection frequency – which does vary widely within a single jurisdiction – on environmental performance and compliance (see Telle 2004; Gray and Deily 1996; Laplante and Rilstone 1996; Eckert 2004; Earnhart 2004).

In the present project, some analysis has been undertaken on the determinants of undertaking concrete actions and improving environmental performance with respect to air and water pollution, as well as solid waste. In Chapter 3, Johnstone et al. find that perceived policy stringency consistently appears to be significant. Reported frequency of inspections is also a significant determinant of environmental performance and actions. However, when looking at the determinants of environmental performance, the inspections data may be capturing two effects – targeting and stringency. For instance it is possible that environmental agencies are using environmental performance to target weak performers (implying a negative relationship),[5] but that the effect of being inspected ultimately improves environmental performance (implying a positive relationship). Preliminary work in this area indicates that the former effect is not present in our data (see Johnstone and Scapecchi 2004).[6]

The role of instrument choice is less evident. Performance standards – perhaps the most common policy instrument actually applied – have a positive influence in a large number of models. Reliance on input taxes occasionally has a negative influence and there is no obvious reason why this may be the case – except perhaps that they are often set too low for political reasons and once in place incentives to introduce other measures as complements are less acute (or else they would be insignificant and not significantly negative).

In the research undertaken by Darnall et al. reported in Chapter 6, anticipated cost savings appear to play a significant role in encouraging improved environmental performance with respect to natural resource use and solid waste generation, but not wastewater effluent and air pollution. This is not surprising since in the former two cases there is likely to be a much stronger relationship between private commercial interests (material and resource efficiency) and public environmental goals (reduced environmental externalities).

Private managerial initiatives are of growing interest to public policy makers, and as such policy incentives to encourage their use increase in importance. More attention is being paid to the role of environmental management systems and tools on the ultimate objective of public environmental policy – improved environmental performance or compliance (see Anton et al. 2002, Anton et al. 2004 and Dasgupta et al. 2000 for recent analyses). However, their real effect can be difficult to gauge, and the effects of public policy incentives may be different from that initially foreseen. For instance, and as noted above, the positive role of perceived reduction in inspection frequency for facilities with an EMS raises significant concerns about the true effect of an EMS on environmental performance, depending upon the motivation for its introduction.

However, despite such reservations, in the work undertaken in the project the presence of an EMS is consistently shown to have a significant positive impact on performance and innovation (this volume, Chapter 5, Frondel et al.; Chapter 3, Johnstone et al.; and Chapter 4, Arimura et al.). The results are somewhat less significant when possible endogeneity is addressed – that is, when the decision to implement an EMS and to undertake other environmental initiatives are modelled as interrelated decisions. This is significant if one wishes to evaluate whether EMSs actually bring about improved environmental performance, rather than just being a reflection of such an improvement. For those facilities with EMSs in place, certification and (less frequently) length of time since implementation appear to be significant influences on the likelihood of reporting reduced environmental impacts (this volume, Chapter 3, Johnstone et al.).

Facilities were also requested to indicate whether the actions they had undertaken were more closely characterized as changes in production processes (CPP) or end-of-pipe (EOP) abatement and resource recovery. A large majority of facilities in all countries report that the nature of environmental measures undertaken to reduce pollution emissions and/or reduce resource use relate more closely to more far-reaching changes in production processes rather than end-of-pipe abatement or resource recovery (see Figure 1.10). This is most pronounced in Japan and (to a somewhat lesser extent) France. Germany has the smallest proportion of facilities which report having undertaken CPP rather than EOP, a finding which Frondel et al. (this volume, Chapter 5) attribute to the preponderance of direct forms of regulation.

These results are interesting because they indicate the extent to which facilities may be realizing economies of scope between production of the primary outputs and the mitigation of environmental impacts. However, given that such opportunities are closely linked with sectoral characteristics (that is, since technological opportunities are likely to vary) and policy frameworks (that is, since some policies will discourage the realization of economies of scope), this is a good illustration of the need to undertake more formal multivariate analysis. For instance, both Frondel et al. (Chapter 5) and Labonne and Johnstone (2006) find some support that 'flexible' policy instruments (performance standards and market-based instruments) tend to encourage the use of changes in production processes rather than end-of-pipe abatement. As noted, the study by Labonne and Johnstone (2006) also finds that the institutional location of the person responsible for environmental matters has an influence.

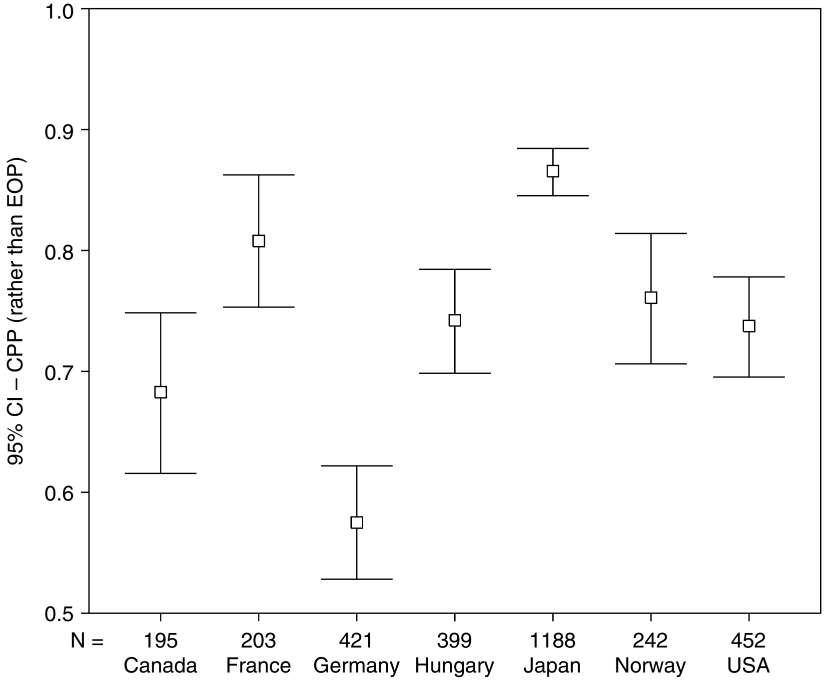

Figure 1.10 Primarily changes in production processes rather than end-of-pipe technologies

Using a different estimation framework, in Chapter 5 Frondel et al. find that facilities that reported cost savings were an important motivation for their environmental practices are more likely to undertake a change in production process rather than end-of-pipe technologies. In country-specific estimations they also find significant differences in the relative role of factors which are internal to the firm (that is, management employees) and external to the firm (that is, sources of finance). For instance, while the former are important in Germany, in Hungary it is the latter which play a more determinant role.

Not surprisingly, most facilities report having undertaken more significant measures in the area of production processes rather than product design, with Germany (less than 10 per cent) having the lowest proportion of facilities having done so in the latter area, and Japan the highest (greater than 20 per cent). However, it must be recognized that since product design is likely to be a firm-level rather than a facility-level responsibility, the multivariate analyses undertaken in these areas needs to be interpreted with particular care.

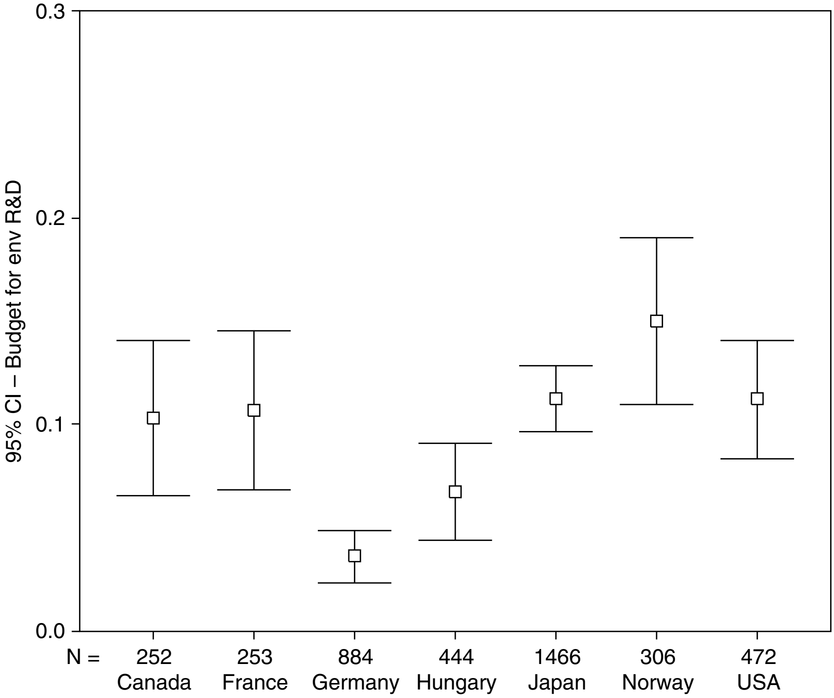

Figure 1.11 Reported percentage of facilities with R&D budgets for environmental matters

The OECD project is one of the few studies which has gathered data on environmental research and development. The number of facilities which report having a separate budget for research and development is given in Figure 1.11. This indicates that on average somewhat less than 10 per cent of the total report having such a budget, with the lowest percentage being in Germany and the highest in Norway. Facilities and firms were also requested to report on the percentage of total R&D budgets devoted to environmental matters.

Of the approximately 400 facilities reporting that they had a budget, there were 275 responses to the quantitative question, and when used in conjunction with the binary question reported on above, interesting studies on the influence of R&D on environmental actions and innovations can be undertaken using Tobit analysis. For instance, in Chapter 4 Arimura et al. report that larger facilities are more likely to undertake environment-related research and development (even when normalized). Surprisingly, facility age has no influence. (See also Johnstone and Labonne 2006.)

Arimura et al. also find that perceived policy stringency is the overriding determinant, but that policy instrument choice only has an indirect influence through the role of environmental accounting. Indeed, the role of the latter seems key, and the decision to invest in research and development appears to be closely bound up with the decision to implement an environmental accounting scheme, highlighting the links between management and technological initiatives.

The links between environmental and commercial performance lies at the heart of the discussions about possible 'win–wins'. Research undertaken by Hart and Ahuja (1996), King and Lenox (2001), Khanna and Damon (1999), Telle et al. (2004) and Konar and Cohen (1997) has examined this relationship empirically. In Chapter 6, Darnall et al. apply multivariate probit analysis and find that environment performance with respect to five different impact variables (natural resource use, solid waste generation, wastewater effluent, air pollution, global pollutants) is positively and significantly related to commercial performance (as measured by reported profits in the previous three years). In addition, the nature of the market appears to matter. Larger facilities which operate in more concentrated markets which are international in nature are more likely to report positive profits. Interestingly in their model, regulatory stringency has a negative influence on commercial performance – that is, there is little evidence of policy 'win–wins'. However, environmental performance generally does result in improved commercial performance.

VI. CONCLUSIONS

This introductory chapter has sought to provide a broad overview of the data collected in the OECD project 'Environmental Policy and Firm-Level Management' and to summarize some of the main results of the analyses undertaken. The database is particularly rich with respect to the public environmental policy framework, environmental and general management practice, and innovation practices, and it is in these areas that the project has focused. While there are some shortcomings associated with a survey-based project of this kind (that is, potential sample and strategic bias, single cross-section, qualitative nature of the variables), the flexibility of the survey instrument and the comprehensiveness of the data collected are significant strengths.

Too vast to summarize succinctly, the full results of this work are presented in the analytical chapters prepared on the determinants of environmental management practices (Chapter 2, Henriques and Sadorsky), environmentally beneficial investments and performance (Chapter 3, Johnstone et al.), environment-related research and development (Chapter 4, Arimura et al.), the propensity to invest in cleaner production technologies (Chapter 5, Frondel et al.), and the links between commercial and environmental performance (Chapter 6, Darnall et al.).

In general, one striking feature of the research undertaken is the dominant role played by the public policy framework, and particularly the perceived stringency of the policy framework. In almost all of the models, perceived policy stringency is the single most important factor driving environmental investment, technological innovation and reported performance. This result is hardly surprising, but it is reassuring. However, the role of policy stringency on environmental management is more ambiguous, with the role of policy stringency dependent upon the measure of environmental management adopted in the analysis.

Reassuringly, inspection frequency also plays an important and positive role in environmental performance and research and development. However, there are concerns about the use of such data in the context of a cross-section study. If environment agencies are targeting facilities on the basis of past environmental performance (which seems likely), teasing out the true role of inspection frequency can be difficult without the use of panel data.

Instrument choice matters as well, but mainly in terms of the nature of practices adopted, and not so much environmental performance *per se*. More specifically, there is some support for the role of more flexible policy instruments on the decision to invest in cleaner production methods and to invest in environment-related research and development. Thus, the empirical work indicates that public policy factors play a role in decisions to invest in environmental research and development and in far-reaching changes in production processes. More 'flexible' instruments are more likely to result in innovative strategies. This is hardly surprising since relative to prescriptive policies, such policy measures give facilities and firms the scope to realize the benefits from such innovation.

However, there is little evidence to support their use in terms of environmental effectiveness at the level of the individual facility, a result which is hardly surprising. Arguments in favour of the use of economic instruments are based largely upon their benefits in terms of static efficiency gains and dynamic incentives, and not in terms of environmental effectiveness *per se*.[7] Moreover, it must be emphasized that the use of self-reported data is problematic as a means to address this issue.

In addition, environmental management seems to have a distinct influence on environmental performance and innovation. Manufacturing facilities which introduce EMSs and other environmental management tools have better and more innovative environmental performance. These results hold even when the estimation framework applied reflects the endogeneity which exists between management and investment decisions.

Policy incentives appear to encourage the implementation of environmental management systems and the designation of somebody as being explicitly responsible for environmental matters, but do not have an effect on the certification decision. Of the different incentives provided, the perception of reduced inspection frequency and the provision of financial assistance appear to be most important. However, further work is required to evaluate precisely what this means for public policy. If EMSs are an intelligent endogenous response on the part of facilities to meet given environmental objectives, a sound general environmental policy framework is likely to be more important than targeted incentives for their introduction.

Work on the links between environmental performance and commercial factors found that environmental performance has a positive influence on profitability. Larger facilities which operate in more concentrated markets which are international in nature are more likely to report positive profits. Interestingly, regulatory stringency has a negative influence on commercial performance – that is, there is little evidence of policy 'win–wins'. However, environmental performance in and of itself has a positive effect on profitability. Thus, even if there are few policy-induced 'win–wins', there may be significant opportunities for profitable investments which reduce environmental impacts.

And finally, environmental management, performance and innovation differ widely across firms and facilities. Firm size, the nature of the market in which they compete, and other factors play a role in determining facilities' environmental strategies. However, from this finding it should not be assumed that 'tailored' environmental policies are required, since these differences may just reflect efficient responses for firms and facilities with different characteristics. Nonetheless, it is clear that there may be specific policy requirements in some areas – such as small and medium-sized enterprises or specific manufacturing sectors – an area which the project has not yet examined.

NOTES

1. See Appendix 1 for a list of the research teams involved, as well as the government advisory group which has overseen the project.
2. See Appendix 2 for a description of survey design. The questionnaire is available at www.oecd.org/env/cpe/firms.
3. In a review of 183 studies based on business surveys published in academic journals Paxson (cited in Dillman 2000) reports an average response rate of 21 per cent.

4. Personal communication from Mr Koichi Kawano, Japanese Ministry of the Environment.
5. See Harrington (1988) for the original treatment of this issue, which has since spawned a very rich literature.
6. However, given the absence of time-series data ideal tests of this issue could not be conducted. In addition, it does not appear – as is often surmised – that inspectorates are using the presence of an EMS as a proxy for good environmental performance, and thus reducing inspection rates.
7. Although, if enforcement is strict, cap-and-trade systems are likely to be more environmentally effective than any direct regulation, since the total level of emissions is regulated (irrespective of firm entry), and not just plant-level emissions.

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APPENDIX 1A

Table 1A.1 Descriptive statistics for selected variables

	N	Variable format	Mean	Std. deviation
Person with explicit responsibility for environment	4171	Binary	0.703189	0.456907
Has facility implemented an EMS	4002	0 = No 1 = In progress 2= Yes	0.558721	0.64581
If yes, year implemented	1207	Numeric	1999.584	3.257752
If EMS, certification	1302	Binary	0.860983	0.346097
Actions to reduce use of natural resources (last 3 yrs)	3792	Binary	0.762922	0.425347
Actions to reduce solid waste generation (last 3 yrs)	3834	Binary	0.817684	0.386155
Actions to reduce wastewater effluent (last 3 yrs)	3468	Binary	0.74308	0.436998
Actions to reduce local/regional air pollution (last 3 yrs)	3135	Binary	0.624561	0.484313
Actions to reduce global pollutants (last 3 yrs)	2737	Binary	0.380709	0.48565
Actions to reduce soil contamination (last 3 yrs)	2690	Binary	0.497398	0.500086
Actions to reduce risk of severe contamination (last 3 yrs)	3127	Binary	0.692677	0.461458
Change in production process rather than end-of-pipe	3100	Binary	0.767742	0.422341
Change in use of natural resources (last 3 yrs)	3619	Scale (1–5)	2.481625	0.761049
Change in solid waste generation (last 3 yrs)	3665	Scale (1–5)	2.432469	0.764156
Change in wastewater effluent (last 3 yrs)	3283	Scale (1–5)	2.541273	0.728784
Change in local/regional air pollution (last 3 yrs)	2848	Scale (1–5)	2.525632	0.686088
Change in global pollutants (last 3 yrs)	2303	Scale (1–5)	2.638732	0.6395
Change in soil contamination (last 3 yrs)	2161	Scale (1–5)	2.660805	0.614022
Change in risk of severe accidents (last 3 yrs)	2783	Scale (1–5)	2.482932	0.667339
Impact of input bans	2730	Scale (1–3)	2.087179	0.779278
Impact of tech-based standards	3010	Scale (1–3)	2.069435	0.708513
Impact of performance-based standards	3380	Scale (1–3)	2.243195	0.679051
Impact of input taxes	3390	Scale (1–3)	2.110324	0.715041
Impact of emission/effluent taxes/charges	3228	Scale (1–3)	2.075898	0.736916

Table 1A.1 (continued)

	N	Variable format	Mean	Std. deviation
Impact of tradeable emission permits or credits	2690	Scale (1–3)	1.727138	0.748301
Impact of liability for env. damages	3472	Scale (1–3)	2.257776	0.707675
Impact of demand information measures	3079	Scale (1–3)	1.715817	0.669181
Impact of supply information measures	3239	Scale (1–3)	1.787589	0.668690
Impact of voluntary/negotiated agreements	3073	Scale (1–3)	1.788155	0.678705
Impact of subsidies/tax preferences	3186	Scale (1–3)	1.872567	0.741728
Impact of technical assistance programmes	2987	Scale (1–3)	1.707399	0.679887
Approximate age of your facility	3749	Numeric	36.13481	21.58165
Does facility have budget for env. research/development	4077	Binary	0.092961	0.290413
Change in value of shipments from facility in last 3 yrs	4045	Scale (1–5)	2.918912	1.078222
Assessment of overall business performance	4017	Scale (1–5)	3.460294	0.989476
Is your firm listed on a stock exchange?	4139	Binary	0.167432	0.373406
How many people employed by your facility in last 3 yrs	3832	Numeric	352.2753	880.9601
Does your firm have an environmental department?	4104	Binary	0.483187	0.499778

2. Environmental management systems and practices: an international perspective[1]

Irene Henriques and Perry Sadorsky

I. INTRODUCTION

In the last decade, the trend towards promoting voluntary action and pollution prevention as opposed to mandatory (command-and-control) environmental regulations that prescribe quantity limits on pollutants has increased as more governments worldwide faced and continue to face limited environmental enforcement budgets (Mintz 2001; Cohen 1998). The interest in promoting voluntary environmental action and pollution prevention has been accompanied by a growing number of business-initiated actions to change corporate culture and management practices via the introduction of environmental management systems (EMSs), industry-level codes of environmental management and international EMS certification programmes such as the International Standards Organization (ISO). EMSs represent an organizational change within corporations and an effort for self-regulation by defining a set of formal environmental policies, goals, strategies and administrative procedures for improving environmental performance (Coglianese and Nash 2001). In the environmental management literature, much research has been undertaken on the determinants of implementing environmental management practices, policies or systems of firms in certain industries within a specific country (Henriques and Sadorsky 1999; Darnall 2003; Sharma 2000). From an international perspective, however, little research has been undertaken and even less so at the facility level.

A large cross-OECD industrial survey was conducted to obtain a better understanding of a firm's commercial motivations, its decision-making procedures and its organizational structure *vis-à-vis* the design and implementation of environmental management systems (EMS) and practices. This chapter assesses the determinants of having in place an environmental management system or practices. More specifically, this chapter provides empirical results regarding what determines a facility's choice as to: (1) whether or not it should introduce an environmental management system; (2) whether or not to engage someone to be responsible for environmental matters; (3) whether or not it should introduce a certified environmental management system (ISO 14001 or EMAS); and (4) whether or not to implement a number of specific environmental management practices.

II. OBJECTIVE

The objective of this chapter is to present our findings addressing the answers to the following four questions regarding a facility's commitment to the natural environment:

1. What factors influence whether or not a facility will implement an environmental management system (EMS)?
2. What factors influence whether or not a facility will have an individual who is explicitly responsible for environmental concerns?
3. What factors influence whether or not a facility will certify its EMS?
4. What factors influence the comprehensiveness of a facility's EMS as measured by the number of environmental practices employed?

In other words, we identify four levels of commitment to the natural environment. The first is whether a facility has an EMS with no assumption as to the level of commitment insofar as environmental practices employed are concerned. The second level of commitment is whether the facility has a person explicitly responsible for environmental issues. The third describes a higher level of commitment in that it is validated by third-party certification while the fourth addresses the comprehensiveness of a facility's EMS.

Table 2.1 summarizes the dependent variables used to empirically test these questions and notes any changes made to the original data. (The following website, http://www.oecd.org/env/cpe/firms, provides the questionnaire and Table 2C.1 in Appendix 2C of this chapter provides correlations and descriptive data for the main variables employed.)

The independent variables used in the analyses of the four types of environmental commitment/initiatives include:

- the scope of a facility's market as a proxy for export orientation (*MRKTSCOP*);
- the number of full-time employees in the facility as a proxy for facility size (*FACEMPL*);

Table 2.1 Dependent variables used in analyses

Variable	Question #	Recode	Description
EMS	1.6a	2 = in progress was recoded as 0	EMS or not (0 = no; 1 = yes)
PERSENV	1.1	No change	Person responsible for environmental issues (0 = no; 1 = yes)
CERTIF	1.6b and 1.6d	If *Emscert* = 1 or ISO 14001 = 1 then *Certif* = 1; otherwise *Certif* = 0	Certified EMS or not (0 = no; 1 = yes)
COUNT	1.4a to 1.4i	Sum of environmental practices	Number of specific environmental practices ranging from 0 (none) to 9 (all)

- whether the facility has an environmental R&D budget (*FACRDENV*);
- the facility's overall business performance over the past three years as a proxy for financial flexibility (*FACBPERF*);
- the influence of public authorities (*INFLAUT*);
- the number of times the facility has been inspected in the last three years as a proxy for regulatory monitoring and enforcement (*INSPFREQ*);
- the influence of corporate head office (*INFLCORP*);
- the influence of commercial buyers (*INFLBYRS*);
- the influence of non-management workers (*INFLWORK*);
- the influence of environmental groups (*INFLENGO*);
- whether the facility has implemented a quality management system (*OMPQMS*);
- whether the facility views the use of natural resources as having a significant negative environmental impact as a proxy for the importance of natural resources in the production process (*IMPNR*);
- whether the head office is located in a foreign country as a proxy for foreign ownership (*FRMINTL*);
- whether the firm is listed on a stock exchange as a proxy for shareholder pressure (*FRMQUOT*);
- the impact of voluntary agreements on the facility's production activities (*VOLAGR*);
- the impact of technical assistance programmes on the facility's production activities (*TECHASS*);

- whether regulatory authorities have programmes and/or policies in place to encourage the facility to use an EMS (*PRGEMP*); and
- country dummies to control for country differences and industry dummies to control for industry differences.

The more export-oriented the facility (*MRKTSCOP*), the greater the benefits it may accrue from the more visible actions taken to protect the environment. According to Nakamura et al. (2001), this may occur because foreign customers tend to be less able to monitor the performance of the facility or firm – as a result, more visible signs of environmental commitment such as having an EMS or a certified EMS may legitimize their reason for doing business with the facility (Bansal and Hunter 2003). King et al. (2005) find that the more an organization's customers are located in foreign countries, the greater the propensity for the organization to certify with the ISO 14001 management standard. Hence, we predict that the greater the scope of a facility's market, the more likely it will undertake environmental initiatives.

The impact of facility size (*FACEMPL*) upon the institutionalization of environmental initiatives may involve two contradictory forces (Nakamura et al. 2001). On the one hand, larger organizations may find it more difficult to coordinate their actions and, as a result, find it harder to reach a consensus (Milgrom and Roberts 1992; Mintzberg 1979; Northcraft and Neale 1994). On the other hand, larger facilities may possess the skills, both human and capital, that can facilitate their ability to commit to environmental initiatives. Consequently, the impact of facility size on the implementation of environmental initiatives is indeterminate.

In general, greater investments in environmental research and development (*FACRDENV*) indicate that the organization has the capacity and incentives to cope successfully with the many environmental issues manufacturing facilities may face. Knowledge capital is critical to sustained competitive advantage (Ghemawat 1986). Consequently, we predict that manufacturing facilities that have environmental R&D budgets are more likely to commit to environmental initiatives of all kinds.

The overall business performance of a facility (*FACBPERF*) influences its costs of capital and financial flexibility (Nakamura et al. 2001). Profitable organizations are more likely to pursue environmental initiatives than organizations facing financial difficulties. Furthermore, the implementation of a formal EMS or the certification of that system takes time and can potentially be an expensive undertaking (Melnyk et al. 2003). Consequently, we predict that the greater a facility's financial performance, the greater its ability to commit to environmental initiatives.

A great deal of pressure for improved environmental performance arises from an organization's stakeholders (Freeman 1984; Mitchell et al. 1997). In general, a company faces a daunting array of potential environmental risks connected with various pressure groups which if not addressed may adversely affect a company's bottom line (Henriques and Sadorsky 1996). Consequently, the more pressure a facility is under from different stakeholders to take into account the environmental impact of its actions, the more likely it will implement environmental initiatives. The pressures included in our models are public authorities (*INFLPAUT*), corporate head office (*INFLCORP*), commercial buyers (*INFLBYRS*), non-management workers (*INFLWORK*) and environmental groups (*INFLENGO*).

Public authorities set and influence the regulatory framework in which all firms must operate both today and in the future. If a company or its facilities were to ignore this framework, the potential risks associated with doing so include: (1) unacceptable process and product impacts resulting in regulatory changes; (2) non-compliance penalties; (3) product elimination, substitution and phase-out; and (4) the banning or restriction of raw material inputs. Regulators and government agencies also have the legal power to withhold or grant licenses and approvals, and also the power to impose penalties, fines and legal liabilities on the directors, officers and the firm. In recent years, regulatory agencies have escalated the level of enforcement of penalties and directors' liabilities for environmental accidents (Dean and Brown 1995; Henriques and Sadorsky 1999; Sharma and Vredenburg 1998; Sharma and Henriques 2005). Consequently, greater pressures from public authorities (*INFLPAUT*) are expected to increase the likelihood of environmental initiatives.

The potential risks that the corporate head office faces include criminal liability for violations and the inability to identify and remedy non-compliance or risk problems (Henriques and Sadorsky 1996). Consequently, the objective of head office is often to make sure that their facilities meet regulations. It is not clear, however, that corporate head office can influence the degree to which the environmental initiatives are implemented. Sharma and Henriques (2005), in their examination of environmentally sustainable practices in the forest products sector, found that, more often than not, corporate head offices did not require their facilities to exceed regulations. They also found that facilities tended to be more aware of the realities on the ground relative to their head office. Consequently, we are uncertain as to whether increased pressures from head office (*INFLCORP*) will increase facility-level environmental initiatives.

Given that the majority of our respondents do not sell directly to the end-consumer, commercial buyers are essentially our respondents' customers. Buyers tend to respond positively to a company's actions by purchasing its product. They can also voice their discontent (or their own customers' discontent) by not purchasing the company's product or by putting pressure on the manufacturer to change its process (Greeno and Robinson 1992). Consequently, the greater the pressure exerted by commercial buyers (*INFLBYRS*), the more likely the facility will implement environmental initiatives.

According to Buzzelli (1991), employees are the source of a company's success and successful environmental policy planning requires their participation. The risk that employees pose if they are ignored occur when accidents arise due to a lack of training or awareness and when there is a perceived non-commitment by top management which, in turn, may increase the probability of whistle-blowing (Henriques and Sadorsky 1996). Consequently, facilities that respond to pressures from workers (*INFLWORK*) to take action on environmental matters are more likely to implement environmental initiatives.

Environmental groups can also exert significant pressure via their influence on the legislative process, the shutdown of future development and the use of third-party lawsuits. In other words, these stakeholders can mobilize public opinion in favour of or against a corporation's environmental performance (Henriques and Sadorsky 1999). In many countries, however, business and environmental groups have historically maintained their distance from each other and have tended to have adversarial relationships (Westley and Vredenburg 1991). As a result, we have no expectation as to the sign of this variable (*INFLENGO*).

Regulatory enforcement and monitoring are also critical factors (Cohen 1998). Many empirical studies (Laplante and Rilstone 1996; Magat and Viscusi 1990) have found that both regulatory environmental inspections and the threat of inspections induce firms to comply with environmental regulations. Helland (1998) found that US firms discovered to be out of compliance by regulatory agencies are more likely to be inspected in subsequent periods which, in turn, caused them to be more likely to self-report a violation so as to regain credibility with the enforcement agency. Consequently, we predict that the larger the number of inspections (*INSPFREQ*) to which a facility is subject, the more likely it is that the facility will adopt environmental initiatives.

Implementation of quality management systems such as ISO 9000 is likely to reduce the learning costs associated with implementing an environmental management system (especially a certified management system such as ISO 14001 or EMAS) since both systems are based on similar processes involving continuous improvement (Nakamura et al. 2001). More specifically, for those companies which have already obtained ISO 9001 registration and/or follow total quality management (TQM) system principles, the ISO 14001 registration is a logical next step because it is very similar to ISO 9001 and the principles of TQM. ISO 9000 has several elements that are useful for ISO 14001 implementation – management structure, review meetings, documentation and record procedures, internal audits and procedure for corrective action.

These elements help build organizational capabilities to implement an organization-wide management system with employee empowerment and cross-functional coordination (Barney 1991). Szulanski (1996) finds that major barriers to the transfer of best practice within the firm are knowledge-related factors such as the recipient's lack of absorptive capacity, causal ambiguity and an arduous relationship between the source and the recipient. The implementation of a quality management system suggests that such barriers are low, and a positive relationship is predicted between participation in quality management system (*OMPQMS*) and the commitment to environmental initiatives.

Facilities that use natural resources intensively in their manufacturing processes may be more sensitive to the potential impact the transformation of these resources may have on the environment. This effect is proxied by the response to the significance of the negative impact of using natural resources in their production process (*IMPNR*). We predict that the more significant the impact, the greater the likelihood that the facility will implement environmental initiatives.

Two firm-level variables are introduced to proxy foreign ownership and shareholder pressure. Foreign ownership is proxied by whether the head office is located in a foreign country (*FRMINTL*). According to Nakamura et al. (2001), foreign owners may, on the one hand, be less willing to contribute to the social well-being of the country in which the facility is located and, as a result, less inclined to invest in environmental protection above the level of required regulation. On the other hand, foreign owners may increase environmental protection initiatives to secure goodwill from the regulatory authorities of the host country so as to prevent discrimination or increase their legitimacy in the eyes of these authorities. Consequently, the effect of foreign ownership on the likelihood that the facility will implement environmental initiatives is indeterminate.

Whether the firm with which the facility is associated is listed on a stock exchange (*FRMQUOT*) is used to proxy shareholder pressure. The pressures that shareholders exert over a firm arise as a result of discontent with environmental fines which lower profits, and disillusionment with progress toward environmental goals and with difficulties in raising new capital or attracting new investors due to poor environmental performance (Henriques and Sadorsky 1996). We postulate that firms that are listed on a stock exchange (*FRMQUOT*) are more likely to feel such pressures and, as a result, be more likely to intensify their environmental initiatives in order to gain favour with or maintain their relations with shareholders.

As was the case with the adoption of a quality management system, the adoption or significance of voluntary environmental agreements within industries suggests that the barriers to the transfer of best practice within the firm (such as the recipient's lack of absorptive capacity, causal ambiguity and an arduous relationship between the source and the recipient) are low (Szulanski 1996). In other words, organizations that view the impact of voluntary agreements as being significant (*VOLAGR*) are more likely to intensify their environmental initiatives.

Do government environmental assistance programmes act as complements or substitutes to the implementation of environmental initiatives such as EMSs and/or ISO certification? To answer this question, we include a variable that measures the impact of technical assistance programmes (*TECHASS*). If these programmes are complements, we should observe a positive relationship; if these programmes are substitutes, a negative relationship between this variable and the environmental initiative being modelled will result.

Some countries are considering code-of-conduct programmes that require EMSs. The USEPA, for example, has the Performance Track Program (www.epa.gov/performancetrack) with 300 facilities members, which requires an EMS for membership and sets goals that go beyond compliance. To account for the possibility that facilities may be incited to undertake environmental initiatives to gain membership into such programmes or gain favour with government authorities, we included a variable reflecting whether regulatory authorities have programmes and policies in place to encourage the use of an EMS (*PRGEMP*). Examples of such programmes include reducing the frequency of regulatory inspections, expediting environmental permits, consolidating environmental permits, waiving environmental regulations, reducing the stringency of regulatory thresholds, providing technical assistance, providing financial support, providing special recognition or award, providing preferences for public procurement and/or providing information about the value of environmental management systems. We postulate that facilities that take advantage of such programmes are more likely to implement environmental initiatives.

Finally, country dummies and industry dummies are included to control for country and industry differences, respectively. The omitted country category in our analyses is the United States and the omitted industry category is the chemical products sector. Table 2.2 summarizes the variables used in our analysis of each of the environmental initiatives described in Table 2.1.

Table 2.2 Independent variables used in analyses of environmental initiatives

Variable name	Description	Expected sign	Supporting literature
MRKTSCOP (quest. 5.2)	Scope of facility's market (1 = local; 2 = national; 3 = regional; 4 = global)	+	Proxy for export orientation. Nakamura et al. (2001); King et al. (2005)
FACEMPL (quest. 5.6)	# of full-time employees in facility	?	Proxy for organizational size. Mintzberg (1979); Northcraft and Neale (1994); Milgrom and Roberts (1992)
FACRDENV (quest. 5.8)	Does facility have enviro R&D budget? (0 = no; 1 = yes)	+	Porter and van der Linde (1995); Nakamura et al. (2001)
FACBPERF (quest. 5.11)	Assessment of overall business performance (1 = revenue has been so low as to produce large losses; 2 = revenue has been insufficient to cover costs; 3 = revenue has allowed us to break even; 4 = revenue has been sufficient to make a small profit; 5 = revenue has been well in excess of costs)	+	A measure of facility performance is a proxy for the costs of capital and financial flexibility. Nakamura et al. (2001); Melnyk et al. (2003)
INFLPAUT (quest. 3.1a)	Influence of public authorities (1 = not important; 2 = moderately important; 3 = very important)	+	Henriques and Sadorsky (1996, 1999)
INFLCORP (quest. 3.1b)	Influence of corporate head office (1 = not important; 2 = moderately important; 3 = very important)	?	Henriques and Sadorsky (1996, 1999); Sharma and Henriques (2005)
INFLBYRS (quest. 3.1d)	Influence of commercial buyers (1 = not important; 2 = moderately important; 3 = very important)	+	Henriques and Sadorsky (1996, 1999)
INFLWORK (quest. 3.1i)	Influence of non-management employees (1 = not important; 2 = moderately important; 3 = very important)	+	Henriques and Sadorsky (1996, 1999)
INFIENGO (quest. 3.1l)	Influence of environmental groups (1 = not important;	?	Henriques and Sadorsky (1996, 1999);

Table 2.2 (continued)

Variable name	Description	Expected sign	Supporting literature
	2 = moderately important; 3 = very important)		Westleyand Vrendenburg (1991)
INSPFREQ (quest. 4.4)	The number of times the facility has been inspected in the last three years	+	Proxy for monitoring & enforcement. Laplante and Rilstone (1996); Helland (1998); Magat and Viscusi (1990)
OMPQMS (quest. 1.8a)	Quality management system (0 = no; 1 = yes)	+	Nakamura et al. (2001); Szulanski (1996)
IMPNR (quest. 2.1a)	Use of natural resources as a significant negative impact	+	Proxy for the significance of the negative impact of using natural resources in the production process
FRMINTL (q 6.2)	Head office located in foreign country? (0 = no; 1 = yes)	?	Proxy for foreign ownership. Nakamura et al. (2001)
FRMQUOT (quest. 6.2)	Listed on a stock exchange? (0 = no; 1 = yes)	+	Proxy for shareholder pressure. Henriques and Sadorsky (1996, 1999)
VOLAGR (quest. 4.1j)	Impact of voluntary agreements (1 = not important; 2 = moderately important; 3 = very important)	+	Szulanski (1996)
TECHASS (quest. 4.11)	Impact of technical assistance programmes (1 = not important; 2 = moderately important; 3 = very important)	?	Government assistance programme – potential substitute or complement?
PRGEMP (quest. 4.2)	Do regulatory authorities have programs and policies in place to encourage your facility to use an EMS? (0 = no; 1 = yes)	+	Proxy for government incentive policy to adopt EMS
Industry dummies	Omitted category is chemical products	?	Control for industry differences
Country dummies	Omitted category is the US	?	Control for country differences

III. DATA AND METHODS

A large OECD industrial survey was undertaken to collect the data necessary to answer the questions listed in section II and other related questions. The survey was undertaken by seven participating research teams from Canada, Germany, France, Hungary, Norway, Japan and the United States in the spring of 2003. As discussed in Chapter 1, these firms were sent a survey, in their respective official languages. Follow-up mailings were also conducted during this period to prompt responses. The database consists of approximately 4200 observations from facilities with more than 50 employees in all manufacturing sectors.

Determinants of Having an EMS in Place

Table 2.3 summarizes the number of facilities that have implemented an environmental management system (EMS) by country. The number of facilities that have implemented an EMS vary across countries from a high of 49.6 per cent in Japan to a low of 27.9 per cent in Hungary. Note that in the empirical analysis that follows, we recoded the 'in progress' category as a 'no' response. The methodology used to analyse the factors that influence

Table 2.3 Implementation of an EMS by country

	Has facility actually implemented an environmental management system?			Total
	No	Yes	In progress	
Canada	118	81	57	256
	46.1%	31.6%	22.3%	100.0%
France	107	78	62	247
	43.3%	31.6%	25.1%	100.0%
Germany	572	246	61	879
	65.1%	28.0%	6.9%	100.0%
Hungary	278	129	55	462
	60.2%	27.9%	11.9%	100.0%
Japan	748	736	0	1484
	50.4%	49.6%	0%	100.0%
Norway	193	113	0	306
	63.1%	36.9%	0%	100.0%
USA	91	171	106	368
	24.7%	46.5%	28.8%	100.0%
Total	2107	1554	341	4002
	52.6%	38.8%	8.5%	100.0%

whether or not a facility implemented an environmental management system (EMS) is the probit model. The probit (or logit) model is the natural complement of the regression model in the case where the regressand is not a continuous variable but a state which may or may not obtain, or a category in a given classification (Cramer 1991). Unlike regression analysis, the probit model allows us to interpret the results in terms of utility maximization in situations of discrete choice. More specifically, a facility chooses to implement an environmental management system, or it does not. From an economic standpoint, rational facilities, possessing sufficient information (for example, costs and substitute products), examine the costs and benefits and undertake the project if and only if it is the best choice. In the case of an environmental management system, benefits (monetary and non-monetary) include the acquisition or maintenance of market share, potential efficiency gains and an increased positive reputation. The costs include the costs of implementing and/or certifying the EMS, regulatory compliance costs, and the associated opportunity costs which are defined as the benefits that would have been earned if the facility had undertaken the next-best project.

Determinants of Having a Person Explicitly Responsible for Environmental Issues

Whether or not the facility has a person explicitly responsible for environmental issues is also an indicator of environmental commitment. The methodology used to analyse the factors that influence whether or not a facility has a person who is explicitly responsible for environmental issues is the probit model. From an economic standpoint, rational facilities, possessing sufficient information (for example, costs and substitute services), examine the costs and benefits and hire the individual if and only if it is the best choice. In the case of benefits (monetary and non-monetary), these include potential efficiency gains in everyone knowing who to go to with their concerns regarding environmental matters, and an increased positive reputation. The costs include the costs of hiring and training the individual, and the associated opportunity costs which are defined as the benefits that would have been earned if the facility had used the funds to undertake a different project.

Table 2.4 presents data on the number of facilities by country that have designated somebody as explicitly responsible for environmental issues. The number of facilities that have a person explicitly responsible for environmental issues vary across countries from a high of 95.1 per cent in the United States to a low of 59.5 per cent in Japan. The latter suggests that there are likely to be some interesting country differences insofar as having a person responsible for environmental issues is concerned.

Table 2.4 Person explicitly responsible for environmental issues by country

	Person with explicit responsibility for environment		Total
	No	Yes	
Canada	75	180	255
	29.4%	70.6%	100.0%
France	64	203	267
	24.0%	76.0%	100.0%
Germany	307	590	897
	34.2%	65.8%	100.0%
Hungary	119	347	466
	25.5%	74.5%	100.0%
Japan	604	888	1492
	40.5%	59.5%	100.0%
Norway	45	264	309
	14.6%	85.4%	100.0%
USA	24	461	485
	4.9%	95.1%	100.0%
Total	1238	2933	4171
	29.7%	70.3%	100.0%

Determinants of Having a Certified EMS

The ISO 14001 is an international, voluntary standard for environmental management systems, published by the International Standards Organization (ISO) (Starkey 1998). The ISO 14001 requires implementation of an environmental management system (EMS) in accordance with defined internationally recognized standards (as set forth in the ISO 14001 specification). The ISO 14001 standard specifies requirements for: establishing an environmental policy; determining environmental aspects and impacts of products, activities and services; planning environmental objectives and measurable targets; implementation and operation of programmes to meet objectives and targets; checking and corrective action; and management review (Delmas 2001; Tibor and Feldman 1996).

This standard is primarily concerned with what the organization does to minimize harmful effects on the environment caused by its activities. ISO 14000 concerns the way an organization goes about its work, and not directly the results of this work. In other words, it concerns processes, and not products – at least, not directly. As noted by Nakamura et al. (2001), ISO 14001 is a standard of environmental management systems, not of environmental performance.

According to the ISO survey of ISO 9000 and ISO 14001 certificates up to and including December 2002, at least 49 462 ISO 14001 certificates had been awarded in 118 countries. The latter reflects an increase of 34.5 per cent over 2001. What may have prompted such an increase? According to the ISO 14001 information centre (see http://www.iso14000.com/), some reasons for this increase include: (1) the possibility that conformity with ISO 14001 may become a contractual requirement of customers in both the US and the European Community; and given that ISO 14000 is a continuation of the ISO 9000 Product Quality standard, (2) the possibility that ISO 14001 may eventually become a requirement for attaining ISO 9000 recertification. In other words, companies may need to conform to ISO 14001 guidelines to remain competitive in the global market place.

A competing voluntary environmental standard is EMAS (Eco-Management and Audit Scheme). EMAS is a voluntary EMS standard developed in Europe. Although the EMAS system was developed before the development of ISO 14001, the ISO standard appears to be gaining acceptance based on the growing number of European facilities adopting ISO (ISO 2003). The variable reflecting certification, therefore, includes facilities with an EMS and/or ISO 14001 certification.

As in the case of implementing an EMS, a facility chooses to certify its environmental management system or it does not. From an economic standpoint, rational facilities, possessing sufficient information (for example, costs and substitute products), examine the costs and benefits and undertake the project if and only if it is the best choice. In the case of certifying an environmental management system, benefits (monetary and non-monetary) include the acquisition or maintenance of market share, potential efficiency gains and an increased positive reputation. The costs include the costs of implementing and certifying the EMS, regulatory compliance costs, and the associated opportunity costs which are defined as the benefits that would have been earned if the facility had undertaken the next-best project.

To analyse the decision to certify ISO 14001 or EMAS, we used the Heckman selection model. The latter is a two-stage procedure which corrects for sample selection bias in the probit analysis (Heckman 1979). Given that certification is limited to facilities that have adopted an EMS, sample selection bias can limit the generalizability of our results. Hence, we first estimated a probit model for whether or not the facility implemented an EMS. The index function from the probit model is transformed into a hazard rate using the Mills ratio, and the estimated rate, λ, is then included in a second-stage probit model to predict whether the EMS was certified ISO 14001 or EMAS. The independent variables are those described in section II.

Table 2.5 EMS certification by country

	Certified EMS?		Total
	No	Yes	
Canada	25	47	82
	42.7%	53.3%	100.0%
France	28	64	92
	30.4%	69.6%	100.0%
Germany	23	220	243
	9.4%	90.6%	100.0%
Hungary	2	124	126
	1.6%	98.4%	100.0%
Japan	13	486	499
	2.6%	97.4%	100.0%
Norway	25	81	106
	23.6%	76.4%	100.0%
USA	142	99	242
	58.9%	41.1%	100.0%
Total	268	1121	1389
	19.3%	80.7%	100.0%

Table 2.5 presents data on the number of facilities that certified (EMAS or ISO 14001) their EMS by country. The number of facilities which have a certified EMS vary across countries from a high of 98.4 per cent in Hungary to 41.1 per cent in the United States. Although Hungary has the fewest facilities with an EMS, those that do have an EMS had them certified.

The Use of Specific Environmental Practices

Anton et al. (2004) propose another interesting measure of environmental commitment, namely the number of environmental practices undertaken. The number of environmental practices can be used to proxy the extent or comprehensiveness of a facility's environmental management system. As such, we collected data on whether or not the facility had implemented the following practices: (1) had a written environmental policy; (2) used environmental criteria in the evaluation and/or compensation of employees; (3) had environmental training programmes; (4) carried out external environmental audits; (5) carried out internal environmental audits; (6) benchmarked environmental performance; (7) used environmental accounting; (8) had a public environmental report; and (9) had environmental perform-

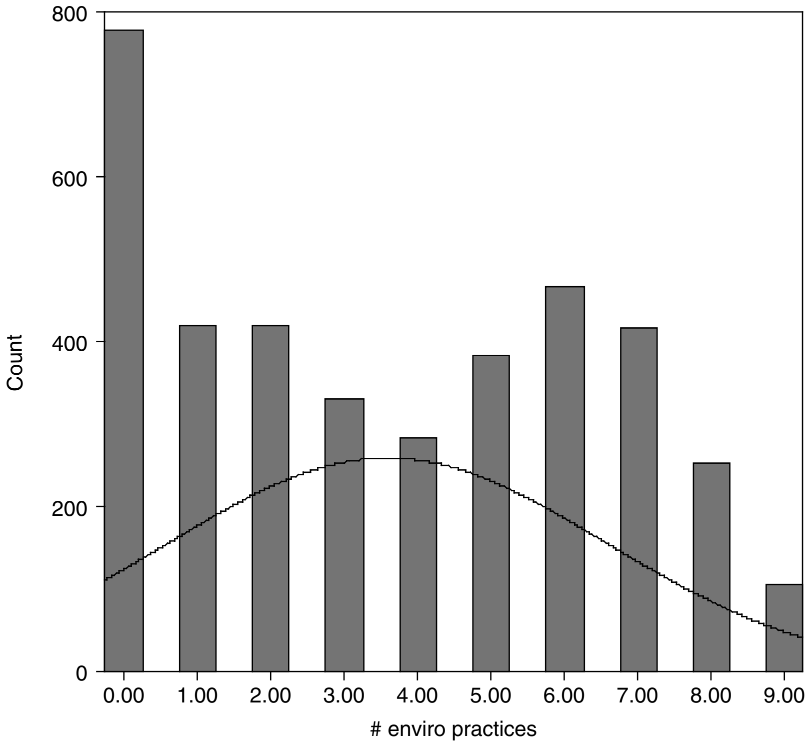

Figure 2.1 International database: distribution of the number of environmental practices

ance indicators or goals. For each facility we took the sum of the number of environmental practices (*COUNT*) which ranges from 0 (none) to 9 (all).[2] Appendix 2A provides figures depicting the number of specific environmental practices undertaken by country.

Figure 2.1 depicts the distribution of the number of environmental practices for the entire database. Seven hundred and eighty facilities had not undertaken any environmental practice while, at the other extreme, only 107 facilities had undertaken all the environmental practices listed. Figures 2B.1 to 2B.7 in Appendix 2B depict the distribution of the number of environmental practices for Canada, France, Germany, Hungary, Japan, Norway and the United States respectively.

Non-parametric tests were conducted to determine whether the distribution of environmental practices differ across countries. Both the Kruskall-Wallis test and the median test results (Tables 2.6 and 2.7) suggest that the seven countries do indeed differ in their level of comprehensiveness insofar

Table 2.6 Kruskall-Wallis test statistics (a, b)

	# enviro practices
Chi-square	324.568
df	6
Asymp. sig.	0.000

Notes:
(a) Kruskal Wallis Test.
(b) Grouping variable: Country of origin of the data.

Table 2.7 Median test statistics (b)

	# enviro practices
N	3870
Median	3.0000
Chi-square	237.469(a)
df	6
Asymp. sig.	0.000

Notes:
(a) 0 cells (0%) have expected frequencies less than 5. The minimum expected cell frequency is 113.6.
(b) Grouping variable: Country of origin of the data.

as environmental practices are concerned. Consequently, we include dummy variables for countries in our analyses.

We measure the determinants of the comprehensiveness of a facility's environmental practices using a standard Poisson model. The Poisson analysis estimates the expected number of environmental practices as a function of firm characteristics. This method, as noted by Anton et al. (2004), does not provide a direct estimate of the impact of firm characteristics on the distribution of environmental practices since it is derived directly from the mean and variance of the environmental practices. Quantile regression analysis, however, can provide information as to the effect of the regressors on each of the quantiles of the distribution of environmental practices by determining whether the distribution's shape is affected (Koenker and Bassett 1978, and Koenker and Hallock 2001, provide excellent descriptions). In other words, do the factors that affect the distribution of the comprehensiveness of a facility's environmental practices affect it in the same manner or do some factors have different effects at the tails of the distribution (different effect at the no or low number of environmental practices versus many or all environmental practices)? The answer to this question can be ascertained using quantile regression analysis.

And finally, correlations and descriptive statistics of all variables used in our models are shown in Appendix 2C. No anomalous correlations or descriptive statistics are observed.

Limitations of Survey Data

All of our analyses were performed using survey data, and as a result, it is important to point out the limitations of using survey data. Standard criticisms of survey data include common method variance (bias), social desirability bias, non-response bias and lack of generalizability (Tan and Peng 2003). Common method variance refers to variance that is attributable to the measurement method rather than to the modelling. To check for common method variance, a factor analysis of the data used in this study from all countries was performed to see if all of the data loaded on one unrotated factor (Harman's single factor test). The results of the factor analysis revealed five distinct factors indicating little evidence of common method bias.

Social desirability bias refers to the situation where individuals attempt to answer survey questions in ways that they deem socially desirable. To address this issue, all respondents were guaranteed anonymity and survey questions addressing environmental concerns were clearly separated in the survey questionnaire from questions pertaining to firm performance. No indication of social desirability bias was found in our pre-test analysis of the survey. Moreover, in the case of Canada, we found no evidence that respondents always over- or under-reported data in a consistent manner.

Non-response bias refers to the possibility that subjects who answer less readily are more like non-respondents (Armstrong and Overton 1977). In Canada, non-response bias was checked by qualitatively comparing the responses of late respondents with those of early respondents. No clear biases emerged. Similar techniques were employed by the researchers in other countries. The study was conducted at the facility level in seven countries and, for most countries, it was not possible to obtain information on the non-respondents because publicly available databases of facilities either do not exist or are not complete. The survey concentrated on the manufacturing industry and, unlike many other studies that focus on a single industry in a single country, our results are much more general in that seven countries were involved. We must note, however, that since the survey was administered to facilities in the manufacturing sector, care must be taken in generalizing the results to other industries. However, we do not believe this to be a problem. The manufacturing sector was chosen because it is commonly accepted that these organizations produce more air, land and water pollution then service organizations do (Stead and Stead 1992). A further limitation of this data set is that it represents a single cross-section in time. While we do not believe any of the data used in our analysis to be overly sensitive to changes across small time periods (two or three years), we do acknowledge that it would be desirable to do a follow-up survey in another three to four years' time.

IV. RESULTS

Table 2.8 (Model 1) presents the probit model results for the determinants of a facility having an EMS. The model's prediction success rate is 73.4 per cent. Facilities with greater market scope and larger facilities are each more likely to have an EMS. Coefficients are considered significant if p-values are less than or equal to 10 per cent. The latter suggests that an EMS may aid in communicating the firm's objectives to all employees. Having an environmental R&D budget, implementing a quality management system, viewing the use of natural resources as having a negative environmental impact, and viewing voluntary agreements as important, each increase the likelihood that a facility will implement an EMS. A facility's overall business performance, however, does not appear to affect a facility's decision to adopt an EMS.

Insofar as stakeholder influences are concerned, the influence of corporate head office, commercial buyers, workers and shareholders (as proxied by whether the firm is quoted on a stock exchange – *FRMQUOT*) each have a positive and significant impact on the likelihood that the facility will implement an EMS. Surprisingly, increased government pressures appear to decrease the likelihood that the facility will implement an EMS while greater regulatory inspections appear to have no significant impact on a facility's decision to adopt an EMS. Environmental groups were also found to have no significant impact (at least not directly) on the likelihood that a facility implements an EMS.

We also find no evidence that foreign ownership (*FRMINTL*) influences the likelihood that a facility will implement an EMS. The use of government technical assistance programmes, however, reduces the likelihood that a facility will have an EMS. The latter suggests that facilities view these programmes as being a substitute for having an EMS rather than a complement. Moreover, facilities that are located in areas where there exist government programmes or policies that encourage EMS use (*PRGEMP*) are more likely to implement an EMS. Relative to the United States, facilities

Table 2.8 Probit regression model results

Independent variables	Model 1: *EMSC*		Model 2: *PERSENV*		Model 3: *CERTIF*	
	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
Constant	−2.71409	0.0000	−1.56111	0.0000	−5.06952	0.0000
MRKTSCOP	0.10630	0.0116	0.13935	0.0025	0.30654	0.0002
FACEMPL	0.00040	0.0002	0.00141	0.0000	0.00035	0.0057
FACRDENV	0.45339	0.0004	0.27791	0.1119	0.55152	0.0118
FACBPERF	0.03086	0.4010	0.12929	0.0030	−0.00371	0.9591
INFLPAUT	−0.19833	0.0030	0.02418	0.7416	−0.16298	0.2262
INFLCORP	0.31665	0.0000	0.23869	0.0006	0.28672	0.0437
INFLBYRS	0.08868	0.1010	0.02872	0.6381	0.28515	0.0073
INFLWORK	0.27240	0.0000	0.23356	0.0012	0.20676	0.1085
INFLENGO	−0.09330	0.1184	0.06162	0.3708	0.13058	0.2527
INSPFREQ	0.00459	0.4372	0.02215	0.1001	0.00032	0.9661
OMPQMS	0.43846	0.0000	0.45868	0.0000	1.25457	0.0000
IMPNR	0.33540	0.0000	0.18899	0.0057	0.45905	0.0002
FRMINTL	0.05721	0.5724	−0.05534	0.6829	−0.03805	0.8335
FRMQUOT	0.21176	0.0245	0.07909	0.5473	−0.02679	0.8751
VOLAGR	0.10927	0.0743	0.15511	0.0427	0.30938	0.0159
TECHASS	−0.16360	0.0097	−0.19059	0.0128	−0.39901	0.0025
PRGEMP	0.37439	0.0000	0.38250	0.0005	−0.39812	0.0073
GERMANY	−0.17052	0.2070	−0.85414	0.0000	1.06216	0.0000
HUNGARY	0.04134	0.8061	−0.45926	0.0384	1.87419	0.0000
JAPAN	0.90173	0.0000	−0.61757	0.0013	2.59227	0.0000
NORWAY	0.67069	0.0001	0.53365	0.0302	1.37953	0.0000
FRANCE	0.09825	0.6176	−0.22923	0.3613	0.77143	0.0151
CANADA	0.00987	0.9539	−0.96083	0.0000	−0.10145	0.6822
Food	−0.64164	0.0000	−0.68191	0.0000	−0.56706	0.0867
Textiles	−0.59530	0.0076	−0.45347	0.0519	−0.15991	0.7821
Wood	−0.45851	0.0157	−0.21844	0.3245	−0.53033	0.0867
Paper	−0.10440	0.4988	−0.26463	0.1286	−0.17455	0.5374
Non-metal	−0.48752	0.0156	−0.20758	0.3839	0.35883	0.3799
Metal	−0.25601	0.0250	−0.17529	0.2210	−0.10286	0.6397
Machinery	−0.16222	0.1450	−0.46207	0.0005	−0.05276	0.8246
Transportation	−0.07837	0.6177	−0.21066	0.3365	−0.11139	0.7015
λ	Na	Na	Na	Na	0.97210	0.0000
McFadden R^2	0.2276		0.2857		0.4545	
P-value of LR	0.0000		0.0000		0.0000	
HL (p-value)	4.356 (0.23)		5.66 (0.13)		7.49 (0.06)	
Andrews (p)	4.56 (0.47)		5.93 (0.31)		92.92 (0.00)	
No. Obs.	1567		1641		700	

Notes: Model 1: probit model – determinants of an EMS (EMSC); Model 2: probit model – determinants of having a person responsible for environmental matters (PERSENV); Model 3: probit model with Heckman sample selection – determinants of a certified EMS (CERTIF).

Huber and White robust standard errors used in calculating coefficient p-values. Hosmer and Lemeshow (1989) and Andrews (1988a, 1988b) goodness-of-fit tests computed using 3 and 5 degrees of freedom respectively.

in Japan and Norway are more likely to implement an EMS. Finally, relative to the chemical products sector, facilities in the food, textiles, wood, non-metal and metal sectors are less likely to implement an EMS.

Table 2.8 (Model 2) presents the probit model results for the determinants of a facility having a person explicitly responsible for environmental matters. This model has a prediction success rate of almost 84 per cent. The results are similar to those obtained for the determinants of a facility having an EMS with the exception of: having an environmental R&D budget, which does not affect whether a facility has a person responsible for environmental issues; the overall business performance of the facility, which has a positive and significant impact on the likelihood that the facility has a person explicitly responsible for environmental issues; the influence of public authorities, which is no longer significant; the influence of commercial buyers, which is not significant; greater regulatory inspections, which has a positive and significant impact on the likelihood that a facility has a person responsible for environmental issues; and shareholder pressures (*FRMQUOT*), which is not significant. Moreover, facilities located in Germany, Hungary, Japan and Canada are less likely to have a person explicitly responsible for environmental matters relative to facilities located in the United States, while facilities located in Norway are more likely to have a person explicitly responsible for environmental issues. Finally, relative to the chemical products sector, facilities in the food, textiles and machinery sectors are less likely to have a person responsible for environmental issues.

Table 2.8 (Model 3) presents the probit model results (prediction success rate of 89 per cent) for the determinants of a facility having a certified EMS with a correction for sample selection bias. The λ coefficient is positive and significant, indicating that self-selection was indeed an issue. Facilities with greater market scope and larger facilities are each more likely to have a certified EMS. A facility implementing a quality management system, having an environmental R&D budget, viewing voluntary agreements as being important, and viewing the use of natural resources as having a negative environmental impact, increases the likelihood in each case that the facility will implement a certified EMS.

A facility's overall business performance, as well as the frequency of regulatory inspections, do not appear to affect a facility's decision to have a certified EMS. Insofar as stakeholder influences are concerned, only the influences of commercial buyers and corporate head office increase the likelihood that the facility will implement a certified EMS. We also find no evidence that foreign ownership (*FRMINTL*) and shareholder influences (*FRMQUOT*) affect the likelihood that a facility will implement a certified EMS. The use of government technical assistance programmes, however, has a negative and significant impact on the likelihood that a facility will implement a certified EMS. Unlike what we observed in Models 1 and 2, relative to the United States, facilities in Germany, Hungary, Japan, Norway and France are more likely to implement a certified EMS while facilities located in Canada are not significantly different from those in the United States. Our industry dummy variable results suggest that facilities in the food and wood sectors are less likely to certify their EMSs relative to facilities in the chemical sector.

The lower rows of Table 2.8 report regression-fit statistics. Likelihood ratio statistics testing all slope coefficients equal to zero show that the null hypothesis of all slope coefficients equal to zero is rejected at the 5 per cent level in each regression. The results from these tests statistics provide very strong evidence of the usefulness of the explanatory variables. Hosmer and Lemeshow (1989) and Andrews (1988a, 1988b) goodness-of-fit statistics compare the fitted expected values to the actual values by group. If these differences are large then the model is rejected. Both the Hosmer and Lemeshow (1989) and Andrews (1988a, 1988b) tests indicate very good goodness of fit for Model 1 and Model 2. In the case of Model 3, however, the results from the test statistics are mixed. The Hosmer and Lemeshow (1989) test indicates a good fit at the 5 per cent level of significance while the Andrews (1988a, 1988b) test indicates rejection of Model 3. Model 3 has a smaller number of observations than either Model 1 or 2 which may account for the discrepancy between the two goodness-of-fit statistics. Model 3 has a high R-squared value and many significant estimated coefficients indicating that, overall, the model is well specified.

Table 2.9 (Model 4) presents the Poisson regression model results for the determinants of the comprehensiveness of the facilities environmental management system as measured by the number of environmental practices implemented. In general, facilities that have a greater market scope, have a greater overall business performance, have an environmental R&D budget, have implemented a quality management system, have a greater number of regulatory inspections, view the importance of the use of natural resources as having a negative environmental impact and view voluntary agreements as important are more likely to implement more comprehensive environmental management practices. These facilities also tend to view all stakeholders as having a positive influence on their decision to implement these practices, with the exception of public authorities (*INFLPAUT*), which have no significant impact, and environmental non-governmental organizations (*INFLENGO*), which also appear to have no significant impact on whether a facility implements more comprehensive environmental practices. Surprisingly, facility size has no significant impact on the comprehensiveness of a facility's environmental practices. As we

Table 2.9 Poisson Regression (Model 4)[a] *– determinants of the comprehensiveness of EMS via the number of environmental practices employed*

Independent variable	Coefficient	z-stat	P-value
Constant	−0.06546	−0.5487	0.5832
MRKTSCOP	0.05317	3.7044	0.0002
FACEMPL	0.00002	1.2566	0.2089
FACRDENV	0.20729	5.9497	0.0000
FACBPERF	0.04442	3.2445	0.0012
INFLPAUT	−0.03955	−1.6050	0.1085
INFLCORP	0.13848	5.2750	0.0000
INFLBYRS	0.04676	2.3556	0.0185
INFLWORK	0.15404	7.1614	0.0000
INFLENGO	0.00781	0.3864	0.6992
INSPFREQ	0.00526	4.0420	0.0001
OMPQMS	0.23227	5.4060	0.0000
IMPNR	0.17885	8.1083	0.0000
FRMINTL	0.07535	2.5361	0.0112
FRMQUOT	0.15515	5.6970	0.0000
VOLAGR	0.10268	4.9206	0.0000
TECHASS	−0.06786	−3.2656	0.0011
PRGEMP	0.10847	4.0758	0.0000
GERMANY	−0.20674	−5.6013	0.0000
HUNGARY	−0.27809	−4.8828	0.0000
JAPAN	−0.22578	−5.3008	0.0000
NORWAY	−0.01649	−0.3095	0.7570
FRANCE	−0.22509	−3.7639	0.0002
CANADA	−0.27068	−5.0663	0.0000
Food	−0.13887	−2.3309	0.0198
Textiles	−0.14504	−1.5127	0.1304
Wood	−0.09488	−1.4723	0.1409
Paper	0.00765	0.1422	0.8869
Non-metal	−0.13149	−1.8049	0.0711
Metal	−0.05238	−1.4286	0.1531
Machinery	−0.02077	−0.5599	0.5755
Transportation	−0.04850	−0.9323	0.3512
Pseudo R^2		0.3554	
P-value of LR statistic		0.0000	
Number of observations		1552	

Notes:
[a] Poisson model with normal heterogeneity – Standard errors corrected for normal heterogeneity.
Huber and White robust standard errors used in calculating coefficient p-values.

found in our previous models, facilities that view technical assistance programmes as important are less likely to implement more comprehensive environmental practices. Relative to facilities in the United States, facilities in Germany, Hungary, Japan, France and Canada are less likely to implement more comprehensive environmental practices. Finally, facilities in the food and non-metal sectors are less likely to implement more comprehensive environmental practices relative to those in the chemical products sector.

As a further check on robustness, each model was re-estimated using ordinary least squares and the stability of the models was analysed using recursively estimated residuals, CUSUM and CUSUM of squares. For each model, the CUSUM and CUSUM of squares values were between the 5 per cent significance levels, indicating no evidence of instability. The recursively estimated residuals from regression Model 1 were all between the upper and lower two standard error bands (95 per cent confidence level). For Models 2, 3 and 4, recursively estimated residuals did reveal a small number of not very large outliers. Overall, these residual tests indicated little evidence of structural instability, helping to confirm the robustness of the regression results.

Compared to other countries, a large number of survey responses came from Japan. Consequently, we were concerned that because of sample composition, our results may be driven by the Japanese data. To check for this effect, we re-estimated the models in Tables 2.8 and 2.9, omitting the Japanese data. For each model, the re-estimated regression results were very similar to the original regression results in terms of parameter coefficients (magnitude, sign and significance) and overall regression fit. As a result, we are very confident that our results are not being driven by the Japanese data.

Table 2.10 presents results of the quantile regression. This method is used to provide an estimate of the effect of the regressors on each of the quantiles in the environmental practices distribution (Koenker and Bassett 1978; Koenker and Hallock 2001). The R^2 are fairly similar across the five regression quantiles, illustrating that the overall model fit is robust. Individual coefficient estimates can, however, vary widely across quantiles. This is evident from the plots depicted in Appendix 2D. More specifically, Appendix 2D presents the quantile regression plots for each coefficient. The solid line represents the point estimates; the dashed line represents the ordinary least squares estimate of the mean effect, with the two dotted lines representing plus or minus one standard deviation. From left to right, the first panel depicts the quantile regression plot of a facility's market scope. Greater market scope (*MRKTSCOP*) provides strong positive support at the lower quantiles of the distribution but weakens significantly as we move

Table 2.10 Quantile regression determinants of the comprehensiveness of environmental management system

Independent variable	Quantile 0.10	Quantile 0.25	Quantile 0.5	Quantile 0.75	Quantile 0.9
Constant	−1.8487*	−2.6441***	−2.4681***	0.1101	2.6854
MRKTSCOP	0.2352	0.3187***	0.0799**	0.2083**	0.1716
FACEMPL	0.0002*	0.0004***	0.0005***	0.0003***	0.0005
FACRDENV	0.7327*	1.5825***	1.1119***	0.9291***	0.9323
FACBPERF	−0.0413	0.1264	0.2928***	0.2138**	0.1866
INFLPAUT	−0.0607	−0.0488	−0.2933**	−0.3637**	−0.3223
INFLCORP	0.1912	0.4151**	0.5767***	0.5132***	0.5226
INFLBYRS	0.0813	0.1655	0.3328***	0.2227*	0.2119
INFLWORK	0.3152	0.5691**	0.7749***	0.8334***	0.4779
INFLENGO	0.1050	0.0324	0.1671**	0.0587	−0.0799
INSPFREQ	0.0399**	0.0227*	0.0316***	0.0213*	0.0056
OMPQMS	0.6916**	0.8797***	0.9806***	0.8117***	0.5540
IMPNR	0.4678**	0.6588***	0.7854***	0.6266***	0.4429
FRMINTL	0.2981	0.5854*	0.4399**	0.3051	0.0483
FRMQUOT	1.3145***	0.9668***	0.7262***	0.5849***	0.3400
VOLAGR	0.5030**	0.6488***	0.4344***	0.3358**	0.3771
TECHASS	−0.1714	−0.5109***	−0.2768**	−0.1847	−0.1283
PRGEMP	0.6581**	0.4701**	0.5424***	0.4811*	0.3051
GERMANY	−1.1603***	−1.3376***	−0.9280***	−0.6086**	−0.7066
HUNGARY	−1.4180***	−1.7971***	−1.6059***	−0.6950*	−0.6999
JAPAN	−1.6780***	−1.5435***	−1.0038***	−0.3947	−0.6138
NORWAY	−0.2583	−0.3010	−0.2869	−0.1637	−0.3481
FRANCE	−1.4359**	−1.2068**	−0.9214**	−0.7300*	−0.9961
CANADA	−1.8467***	−1.5883***	−1.3086***	−0.9044**	−0.7696
Food	−0.7297	−0.8359**	−0.4922*	−0.6964**	−0.2103
Textiles	−0.8222	−0.6977	−0.3928	−0.8474*	−0.4665
Wood	−0.2163	−0.1600	−0.3280	−0.5277	−0.4573
Paper	−0.0488	−0.1653	0.1234	0.0164	0.1003
Non-metal	−0.5187	0.0205	−0.5070	−0.9359**	−0.1841
Metal	−0.2037	−0.2739	−0.3385	−0.5003*	−0.1183
Machinery	−0.4281	−0.3705	0.0141	−0.4392*	−0.3304
Transportation	−0.3756	−0.4596	0.2100	−0.4421	−0.3523
R^2	0.3565	0.3878	0.3913	0.3882	0.3491
Number of observations			1546		

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

across the distribution, suggesting that international exposure tends to give the facility the impetus to take on environmental initiatives. The number of employees in a facility (*FACEMPL*) has a positive and increasing impact throughout the distribution. The impact of whether a facility has an environmental R&D budget (*FACRDENV*) is stronger at the lower quantiles of the distribution. Facility business performance (*FACBPERF*) is weak at the lower quantiles but positive and significant as the number of practices increases. The latter suggests that facilities may be more willing to undertake more environmental initiatives as their business performance improves.

With regards to stakeholder influences, the influence of public authorities (*INFLPAUT*) has a negligible impact at the lower quantiles of the distribution and a negative (and significant) impact on environmental practices as the number of practices increases. The influence of corporate head office (*INFLCORP*) on the number of practices implemented is high throughout the distribution until we reach the higher quantiles where the influence of corporate headquarters wanes. The influence of buyers (*INFLBYRS*), on the other hand, peaks at the midpoint of the distribution, suggesting that their influence is greater at spurring interest in environmental practices but begins to wane as we move along the distribution. The influence of employees (*INFLWORK*), on the other hand, is positive and increasing throughout most of the distribution, suggesting that employees play an important role in the implementation of these practices whether it is a single practice or a host of practices. Interestingly, although the influence of environmental groups (*INFLENGO*) appears to have a negligible impact on the distribution as a whole, the influence of ENGOs across the distribution is mostly concave with its impact increasing until $\tau = 0.5$ where it peaks and decreases as the number of practices increases.

Not surprisingly, the impact of inspection frequency (*INSPFREQ*) is such that it has the greatest positive impact on facilities that have a few environmental practices and the lowest impact on facilities that have implemented a large number of practices. Having a QMS (*OMPQMS*) at the lower quantiles tends to increase the number of environmental practices undertaken with the impact of a QMS peaking at $\tau = 0.75$; that is, when facilities have implemented at least seven practices.

The importance of negative impact of natural resources on the environment (*IMPNR*) is weak at the lower quantiles, suggesting that managerial perceptions regarding environmental matters increases as the facility takes on more environmental practices. Having an international head office (*FRMINTL*) is not significant at the lower or higher quantiles of the distribution but is relevant as we move towards the middle of the distribution. The latter suggests that facilities with international head offices tend to implement more environmental practices. Although being listed on a stock exchange (*FRMQUOT*) has a strong positive impact on the number of environmental practices undertaken, its impact decreases as the number of practices increases.

Voluntary agreements (*VOLAGR*) provide strong positive support at the lower quantiles, but its positive contribution weakens as we move along the distribution. Technical assistance programmes (*TECHASS*), on the other hand, tend to have a strong substitution effect when facilities have undertaken a few environmental practices. Note, however, that this effect is reduced as the number of practices implemented increases. Facilities that take advantage of government programmes that encourage EMS use see a positive (and significant) but decreasing impact as the number of practices employed increases. The latter suggests that such programmes not only encourage EMS adoption, but may also encourage facilities to adopt practices that go beyond those required for EMS certification (ISO 14001 or EMAS).

Finally, the last panels presented in Appendix 2D describe the distribution of each of the country dummies relative to the United States, each of the industry dummies relative to the chemical sector and the constant, respectively. In general, facilities in Germany, Hungary, Japan, France and Canada have fewer environmental initiatives relative to their US counterparts while facilities in Norway are not significantly different from those in the US. At the industry level, relative to the chemical sector, only the food sector undertakes fewer practices.

V. DISCUSSION AND CONCLUSIONS

Four levels of managerial commitment to the natural environment were examined. The first is whether a facility has an EMS with no assumption as to the level of commitment insofar as the environmental practices employed are concerned (Model 1). The second level of commitment is whether the facility has a person explicitly responsible for environmental issues (Model 2). The third level of commitment is whether the facility has a certified (ISO 14001 or EMAS) EMS (Model 3). The latter is a higher level of commitment in that it is validated by third-party certification, while the fourth level of commitment addresses the comprehensiveness of a facility's EMS (Model 4) as measured by the number of environmental practices implemented.

In general, our results from estimating all four models of commitment to the natural environment are quite robust (Table 2.11). Market scope, the influence of corporate head office, the adoption of a quality management

Table 2.11 Summary of results

Independent variables	Dependent variable			
	Model 1: *EMSC*	Model 2: *PERSENV*	Model 3: *CERTIF*	Model 4: Comprehensiveness
Constant	−	−	−	
MRKTSCOP	+	+	+	+
FACEMPL	+	+	+	
FACRDENV	+		+	+
FACBPERF		+		+
INFLPAUT	−			
INFLCORP	+	+	+	+
INFLBYRS	+		+	+
INFLWORK	+	+		+
INFLENGO				
INSPFREQ		+		+
OMPQMS	+	+	+	+
IMPNR	+	+	+	+
FRMINTL				+
FRMQUOT	+			+
VOLAGR	+	+	+	+
TECHASS	−	−	−	−
PRGEMP	+	+	−	+
GERMANY		−	+	−
HUNGARY		−	+	−
JAPAN	+	−	+	−
NORWAY	+	+	+	
FRANCE			+	−
CANADA		−		−
Food	−	−	−	−
Textiles	−	−		
Wood	−		−	
Paper				
Non-metal	−			−
Metal	−			
Machinery		−		
Transportation				
Λ	Na	Na	+	Na

Notes: + (−) indicates the sign of a coefficient which is statistically significant at the 10 per cent level. Na denotes not applicable. Model 1: Table 2.8 – probit model – determinants of an EMS (EMSC); Model 2: Table 2.8 – probit model – determinants of having a person responsible for environmental matters (PERSENV); Model 3: Table 2.8 – probit model with Heckman sample selection – determinants of a certified EMS (CERTIF); and Model 4: Table 2.9 – Poisson regression model – determinants of the comprehensiveness of EMS via the number of environmental practices employed (COUNT).

system, the perception that the use of natural resources has a significant negative impact, and the impact of voluntary agreements each has a positive and statistically significant impact on the level of commitment to the natural environment in each of the four models. Technical assistance programmes have a negative and statistically significant impact on each of the four levels of commitment to the natural environment. The latter suggests that the greater the importance of technical assistance programmes, the less likely it is that facilities will implement environmental management initiatives – in other words, technical assistance programmes are viewed as a substitute for environmental management initiatives rather than a complement. Environmental groups were found to have no impact on any of the models, suggesting that facilities' relationship with environmental groups is more distant than collaborative (Westley and Vredenburg 1991).

We also found some interesting differences across our four models of commitment to the natural environment. Although having an R&D budget increased the likelihood that a facility would implement an EMS, certify their EMS and undertake more environmental practices, it had no impact on whether the facility hired a person responsible for environmental issues. Instead, having positive business performance and increased inspection frequencies were positive contributors to this undertaking.

The influence of stakeholders also differed across the four levels of commitment. Counter to our expectations, public authorities had a negative impact on a facility's adoption of an EMS. Inspection frequencies, however, did increase both the comprehensiveness of a facility's environmental practices and the likelihood that a facility would hire a person responsible for environmental matters. This suggests that although command-and-control itself may discourage voluntary action, if accompanied by proper enforcement and monitoring, a positive outcome may result. Buyers had a positive and significant impact on all environmental initiatives except in the decision to hire a person responsible for environmental issues, while the influence of workers had a positive and significant impact on all but one level of commitment – namely, the decision to certify a facility's EMS.

The certification results (Model 3) provide some interesting differences relative to our other models of environmental commitment. Comparing the certification decision to the EMS decision, we find that the influence of public authorities, the influence of workers and the influence of shareholders (*FRMQUOT*) are no longer significant. We also find that the only influential stakeholders in the certification decision are commercial buyers and head office. The latter suggests that the decision to certify may result from the organization's desire to signal to its buyers that it is a responsible corporate citizen (King et al. 2005). Moreover, facilities located outside of North America are more likely to certify.

One possible explanation for this result is that in Canada and the US, where resistance to regulatory pressures can often pay off via the use of the legal system and/or subversion, facility heterogeneity can be achieved without acquiring and deploying resources and capabilities to deal with their environmental challenges (Henriques and Sadorsky 2003; Darnall and Pavlichev 2003). In other words, an argument can be made that North American facilities have yet to recognize the business case for certifying their EMS. Finally, counter to what we find with the other levels of environmental commitment, government programmes encouraging the use of EMS reduce the likelihood that a company will certify its facility's EMS. This is an important result because it implies that policies that attempt to encourage EMS adoption will not necessarily encourage certification. The decision to certify, therefore, appears to be more complex.

Table 2.12 summarizes the expected sign of each independent variable and whether these were supported by our results. Focusing on the variables for which our expectations (hypotheses) were uncertain, our results suggest that larger firms are better equipped to deal with environmental issues relative to their smaller counterparts, and the influence of head office is critical in building support for environmental initiatives. Furthermore, environmental groups were perceived by facilities to have no impact on their environmental initiatives. Henriques and Sharma (2005), in their examination of stakeholder influence pathways in the forestry sector, also found that environmental groups did not have a direct influence on the sustainability practices of facilities but instead exerted indirect influence via other stakeholders such as customers and the media. Future research would try to assess whether the latter is also occurring at the international level.

According to Nakamura et al. (2001), foreign owners may, on the one hand, be less willing to contribute to the social well-being of the country in which the facility is located and, as a result, less inclined to invest in environmental protection above the level of required regulation. On the other hand, foreign owners may increase environmental protection initiatives to secure goodwill from the regulatory authorities of the host country, so as to prevent discrimination or increase their legitimacy in the eyes of these authorities. Our results suggest that the latter holds only in the case of the comprehensiveness of a facility's environmental practices. In all other cases, whether a facility had a foreign head office had no impact. Future research would attempt to assess the role of head office as well as the head office country location to determine whether institutional pressures from head office have an impact on the type and number of environmental initiatives undertaken by the facility. Anecdotal evidence by such companies as British Petroleum and 3M suggest that facilities,

Table 2.12 Expected sign of independent variables and results

Variable name	Description	Expected sign	Supported by results? (10% level of significance)
MRKTSCOP	Scope of facility's market (1 = local; 2 = national; 3 = regional; 4 = global)	+	Supported by all 4 models.
FACEMPL	# of full-time employees in facility	?	+ in models 1, 2, and 3 suggesting that larger facilities possess the skills to commit to environmental initiatives.
FACRDENV	Does facility have enviro R&D budget? (0 = no; 1 = yes)	+	Supported by Models 1, 3 and 4.
FACBPERF	Assessment of overall business performance (1 = revenue has been so low as to produce large losses; 2 = revenue has been insufficient to cover costs; 3 = revenue has allowed us to break even; 4 = revenue has been sufficient to make a small profit; 5 = revenue has been well in excess of costs)	+	Supported by Models 2 and 4 only. Positive business performance is needed to support more comprehensive environmental initiatives.
INFLPAUT	Influence of public authorities (1 = not important; 2 = moderately important; 3 = very important)	+	Not supported (negative in Model 1).
INFLCORP	Influence of corporate head office (1 = not important; 2 = moderately important; 3 = very important)	?	+ in all 4 models suggesting that corporate head office is an important influence.
INFLBYRS	Influence of commercial buyers (1 = not important; 2 = moderately important; 3 = very important)	+	Supported by all models except Model 2.
INFLWORK	Influence of non-management employees (1 = not important; 2 = moderately important; 3 = very important)	+	Supported by all models except Model 3.
INFLENGO	Influence of environmental groups (1 = not important;	?	No influence.

Table 2.12 (continued)

Variable name	Description	Expected sign	Supported by results? (10% level of significance)
	2 = moderately important; 3 = very important)		
INSPFREQ	The number of times the facility has been inspected in the last three years	+	Supported in Models 2 and 4.
OMPQMS	Quality management system (0 = no; 1 = yes)	+	Supported by all 4 Models.
IMPNR	Use of natural resources as a significant negative impact	+	Supported by all 4 Models.
FRMINTL	Head office located in foreign country? (0 = no; 1 = yes)	?	+ in Model 4 only.
FRMQUOT	Listed on a stock exchange? (0 = no; 1 = yes)	+	Supported by Models 1 and 4.
VOLAGR	Impact of voluntary agreements (1 = not important; 2 = moderately important; 3 = very important)	+	Supported by all 4 Models.
TECHASS	Impact of technical assistance programmes (1 = not important; 2 = moderately important; 3 = very important)	?	− in all 4 Models suggesting that technical assistance programmes are a substitute to environmental initiatives.
PRGEMP	Do regulatory authorities have programs and policies in place to encourage your facility to use an EMS? (0 = no; 1 = yes)	+	+ in Models 1, 2 and 4 but negative in the certification model (Model 3).

whether located in a country with lax or with strong environmental standards, undertake similar environmental initiatives (British Petroleum 2003; 3M 2003).

Another hypothesis for which we were uncertain of the result was whether technical assistance programmes are viewed as a complement or substitute for environmental management systems. Our results suggest that technical assistance programmes are a substitute for all environmental initiatives. Future research would look to see whether this is the case in each of the seven countries and, if so, whether this is viewed as a technical fix to a managerial problem.

Managerial Implications

Our results suggest that the acquiring and/or availability of resources and capabilities (Barney 1991) such as positive business performance, an R&D budget, implementing a quality management system, viewing employees as important players in developing environmental initiatives, viewing voluntary agreements as important and developing international skills (as measured by a facility's market scope) matter insofar as the development of environmental initiatives are concerned. Head office support is also critical (Table 2.12).

Organizations are not immune to external pressures (Freeman 1984; Mitchell et al. 1997) and our results suggest that pressures from buyers and public authorities via monitoring efforts do affect a facility's decision to adopt environmental initiatives. Although environmental groups were found to have no impact on a facility's decision to adopt environmental initiatives, the possibility that they may have an indirect influence cannot be rejected (Table 2.12).

Finally, there exist some significant country differences that managers may find useful insofar as what environmental initiatives facilities in other countries adopt. In the case of the adoption of an EMS, more facilities in Japan and Norway adopt EMSs relative to their US counterparts. In the case of hiring a person responsible for environmental issues, this appears to be more of a US phenomenon with facilities located in Germany, Hungary, Japan and Canada being less likely to do so. While facilities located in Germany, Hungary, Japan, Norway and France are more likely to certify their EMSs, these same countries, with the exception of Norway, tend to have less comprehensive environmental management practices. Such information is useful for anyone interested in establishing facilities in these countries.

Policy Implications

The policy implications of our results are extremely interesting in that they inform policy makers as to the perceived behaviour of our respondents towards government regulation in general, and government programmes more specifically. First, the greater the perceived pressure from public authorities, the less likely it is that facilities will adopt an EMS or undertake more comprehensive environmental initiatives. This effect is somewhat countered by increased monitoring, which increases the likelihood that the facility will hire a person responsible for environmental issues or adopt more comprehensive environmental initiatives.

Second, government programmes may not result in the outcome which the policy maker may be hoping for. For example, our results suggest that technical assistance programmes reduce the likelihood of all four levels of environmental commitment. Consequently, if such programmes are being touted as encouraging environmental initiatives, this is not the outcome. Programmes that explicitly encourage EMS use, however, do increase the likelihood that a facility adopts an EMS, hires a person explicitly responsible for environmental issues and increases the comprehensiveness of its environmental initiatives. These programmes, however, reduce the likelihood that the facility will certify its EMS. The latter suggests that the certification decision is much more complex.

Third, our quantile regression analysis allows us to ask and empirically examine what policies are best for firms which are just starting to undertake environmental practices. Policy makers need to ascertain whether the policies they implement have the same impact across the entire spectrum of environmental initiatives. Our results suggest that inspection frequency has a significant impact on facilities that are just starting to undertake environmental initiatives (lower quantiles) while the influence of public authorities has no significant impact. However, as the number of environmental practices undertaken increases, the influence of public authorities has a negative and significant impact, while the impact of inspection frequencies continues to be positive. Finally, government programmes that promote the adoption of EMS do in fact have a positive impact on the number of practices employed, and may encourage facilities to adopt practices that go beyond those required for EMS certification.

NOTES

1. A project which attempts to bring together researchers, government officials and businesses from seven different countries to formulate and conduct an international survey is no easy feat. From our first face-to-face meeting in Paris in March 2002, we knew that this project would be challenging in that it would require the concerted effort of seven research teams and their respective governments. This project would not have been ossible if not for the tremendous efforts of our project leader Nick Johnstone of the OECD Environment Directorate. Thank you, Nick. We would also like to take this opportunity to thank Environment Canada for their financial support. Peter Sol and Geoff Oliver of Environment Canada were important partners throughout the project. Without listing all of their names, we would like to thank our fellow research colleagues from France, Germany, Hungary, Japan, Norway and the United States. Your feedback on earlier drafts was very much appreciated. We hope to have the opportunity to work together again in the near future. Finally, we would like to dedicate this chapter to Michelle and Victoria, our twin daughters who were born when this project first started.
2. Although a 9 is indeed better than a 0, this variable does not necessarily measure the quality of the EMS since the implementation of, say, three practices may not be the same across facilities. Consequently, all we can say is that it is a proxy for the comprehensiveness of the EMS.

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APPENDIX 2A THE NUMBER OF ENVIRONMENTAL MANAGEMENT PRACTICES UNDERTAKEN BY COUNTRY

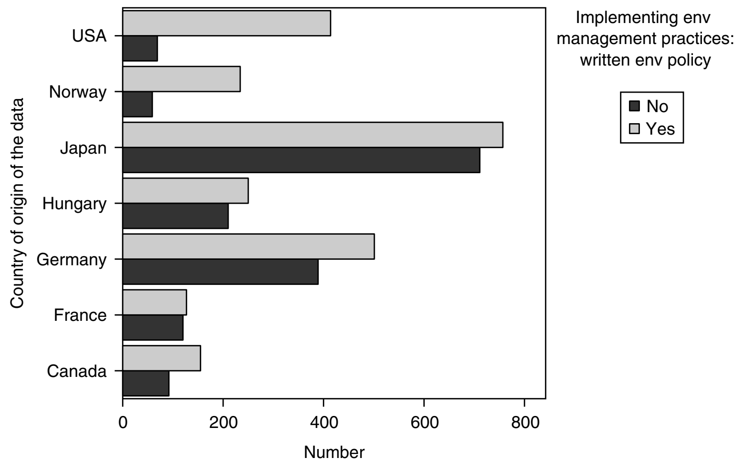


Figure 2A.1 Written environmental policy?

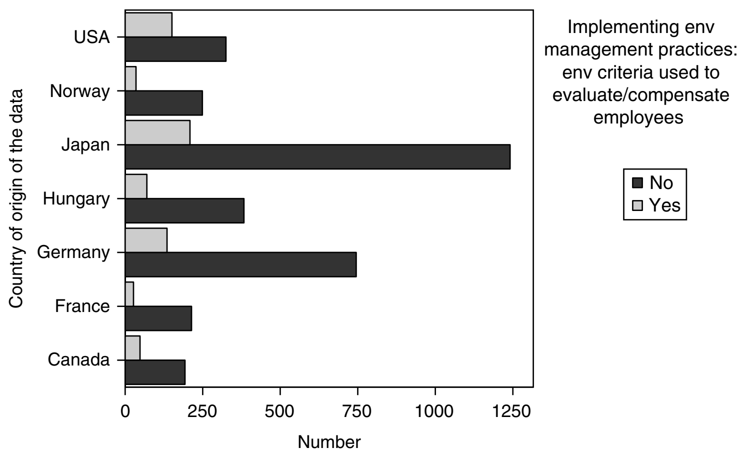


Figure 2A.2 Environmental criteria used in evaluation and/or compensation of employees?

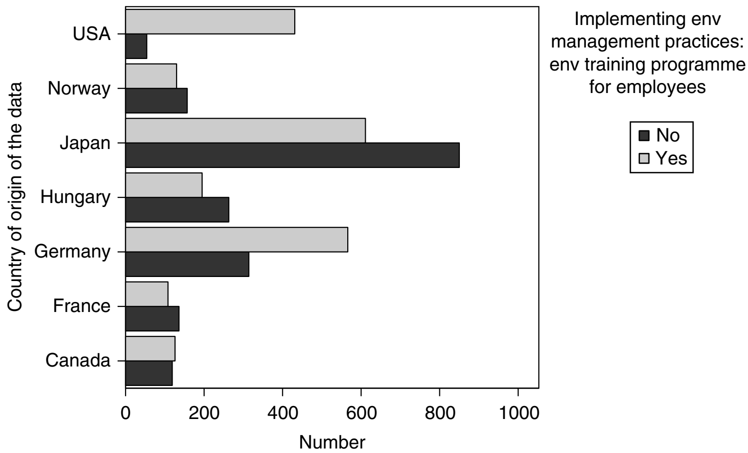


Figure 2A.3 Environmental training program?

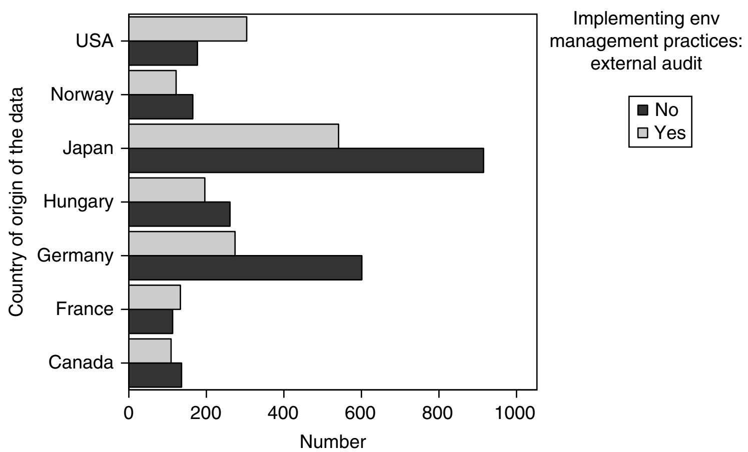


Figure 2A.4 Carry out external environmental audits?

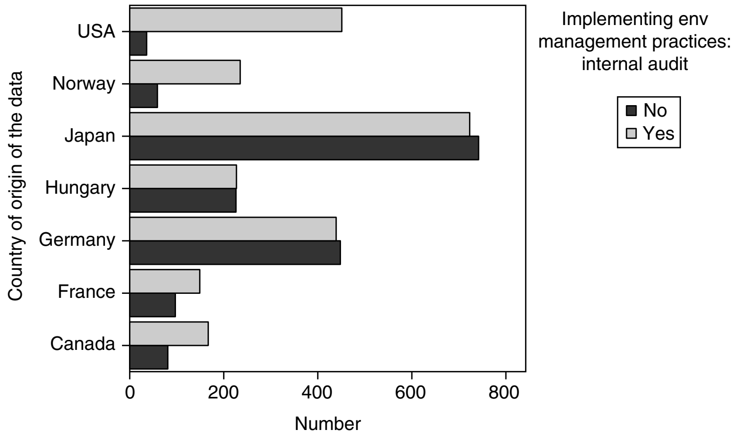


Figure 2A.5 Carry out internal environmental audits?

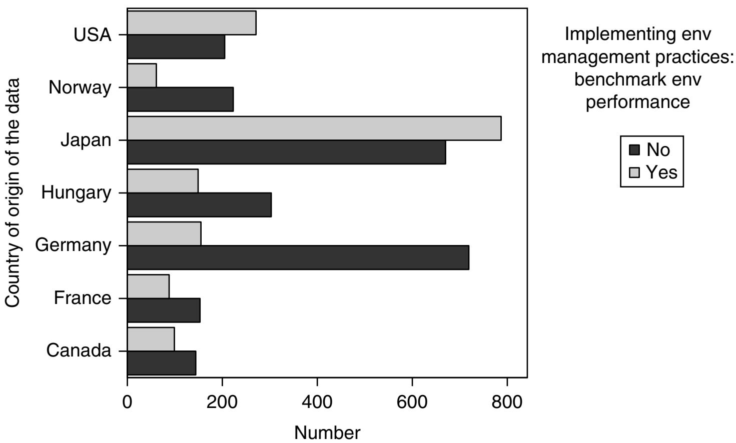


Figure 2A.6 Benchmark environmental performance?

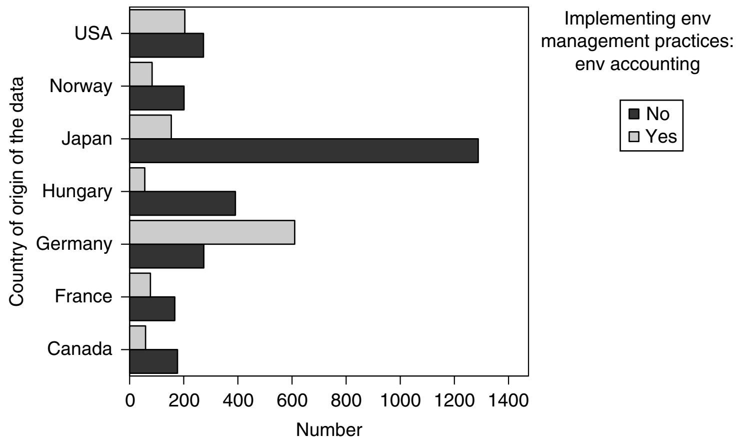


Figure 2A.7 Environmental accounting?

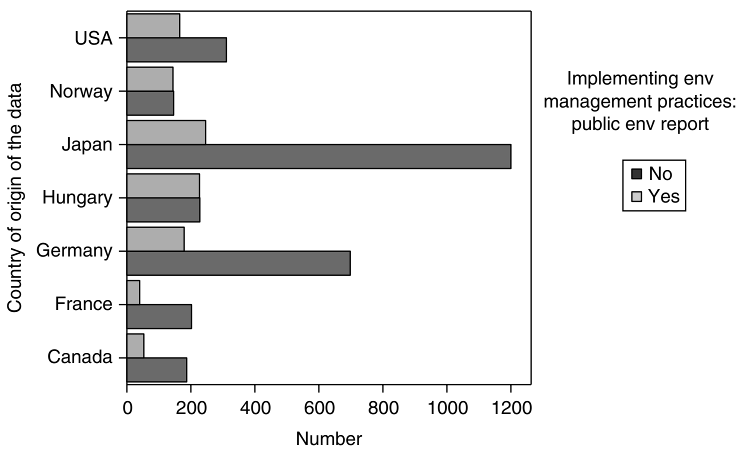


Figure 2A.8 Public environmental report?

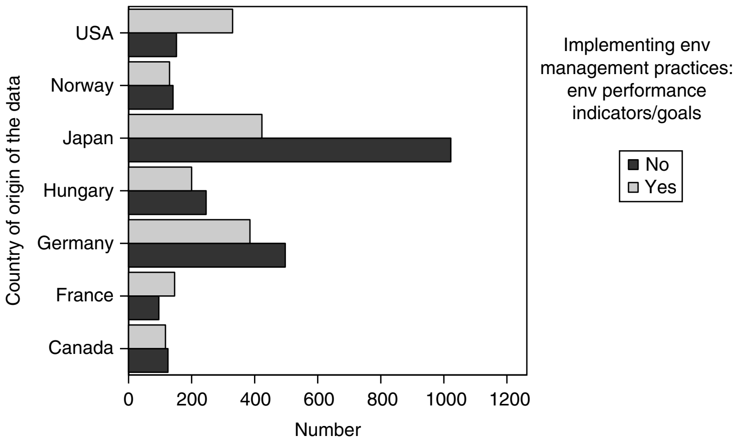


Figure 2A.9 Environmental performance indicators/goals?

APPENDIX 2B DISTRIBUTION OF ENVIRONMENTAL MANAGEMENT TOOLS

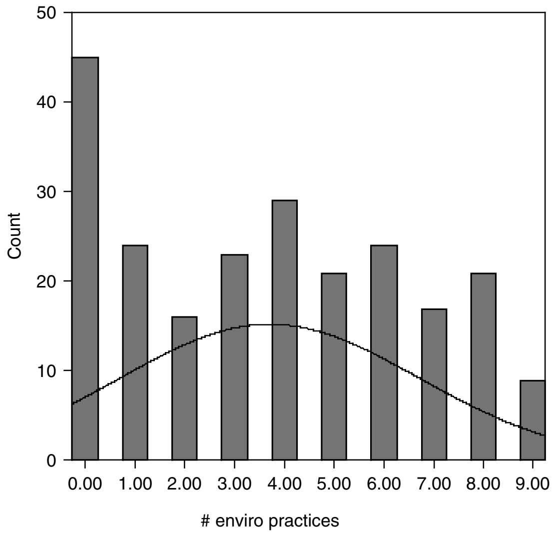


Figure 2B.1 Canada

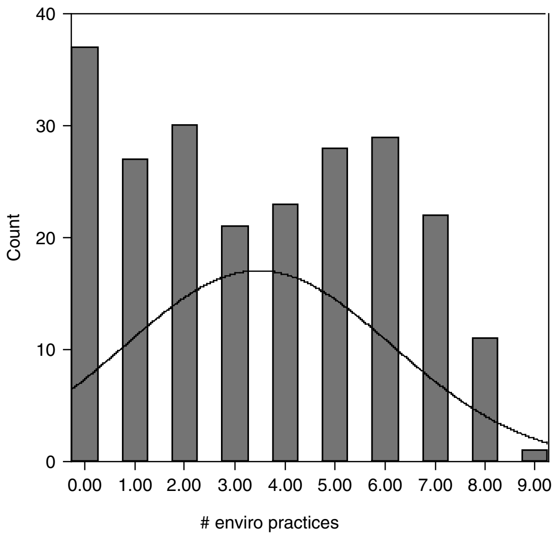


Figure 2B.2 France

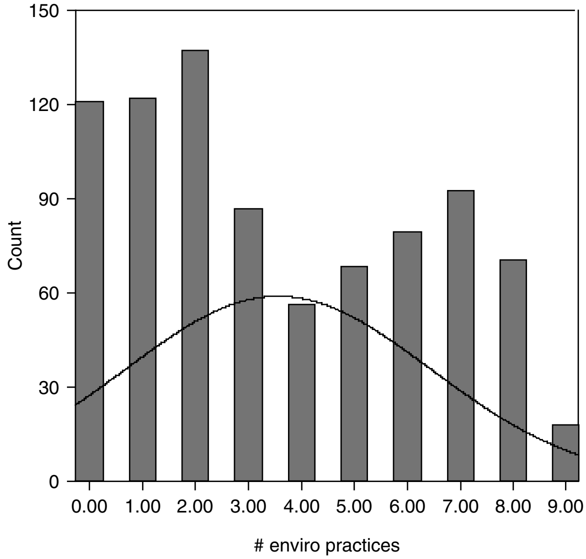


Figure 2B.3 Germany

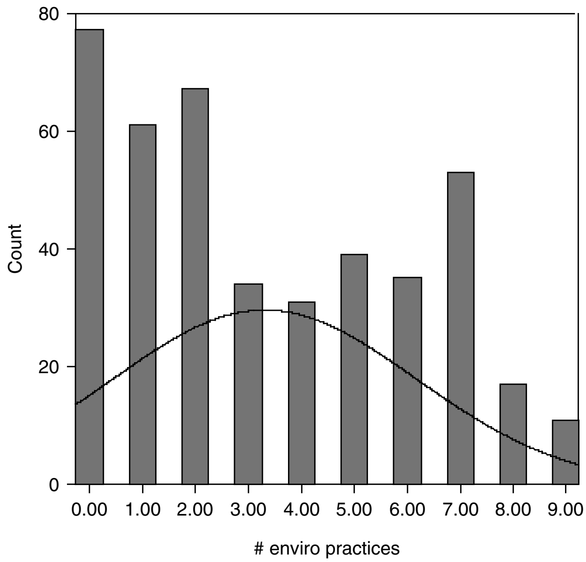


Figure 2B.4 Hungary

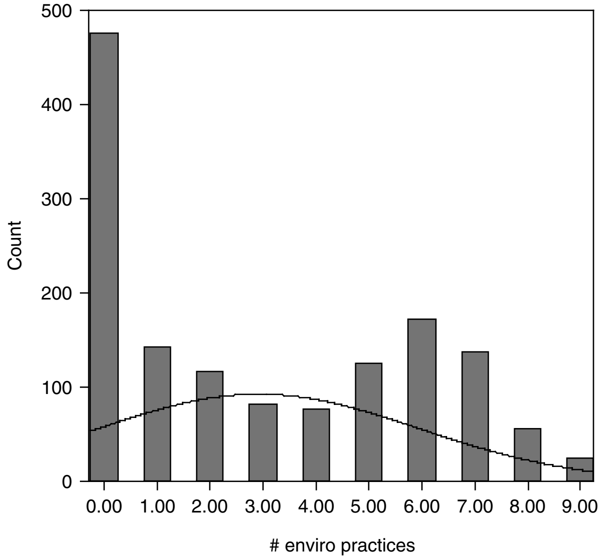


Figure 2B.5 Japan

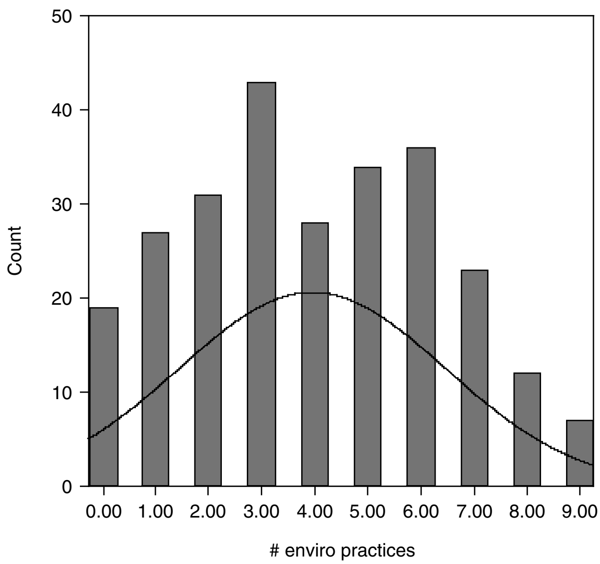


Figure 2B.6 Norway

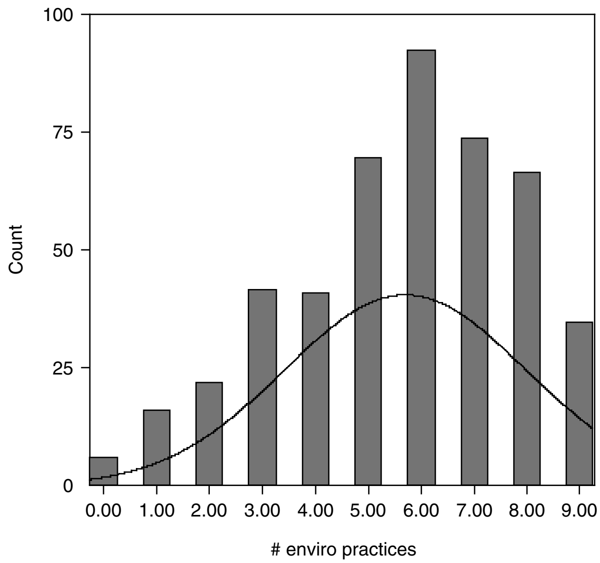


Figure 2B.7 USA

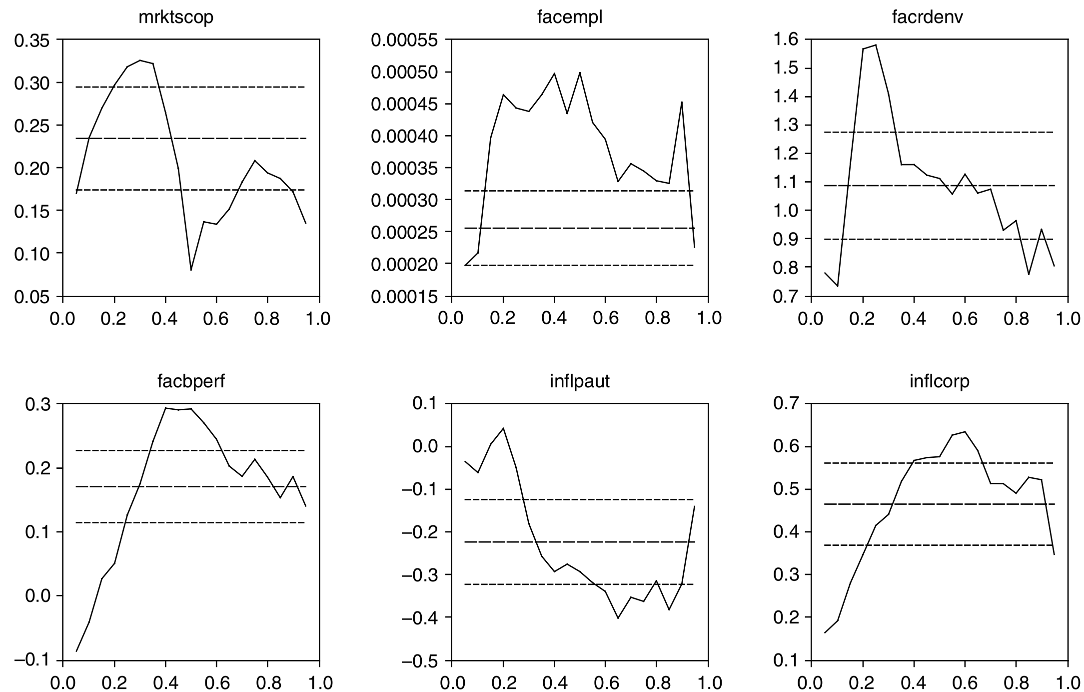
APPENDIX 2C

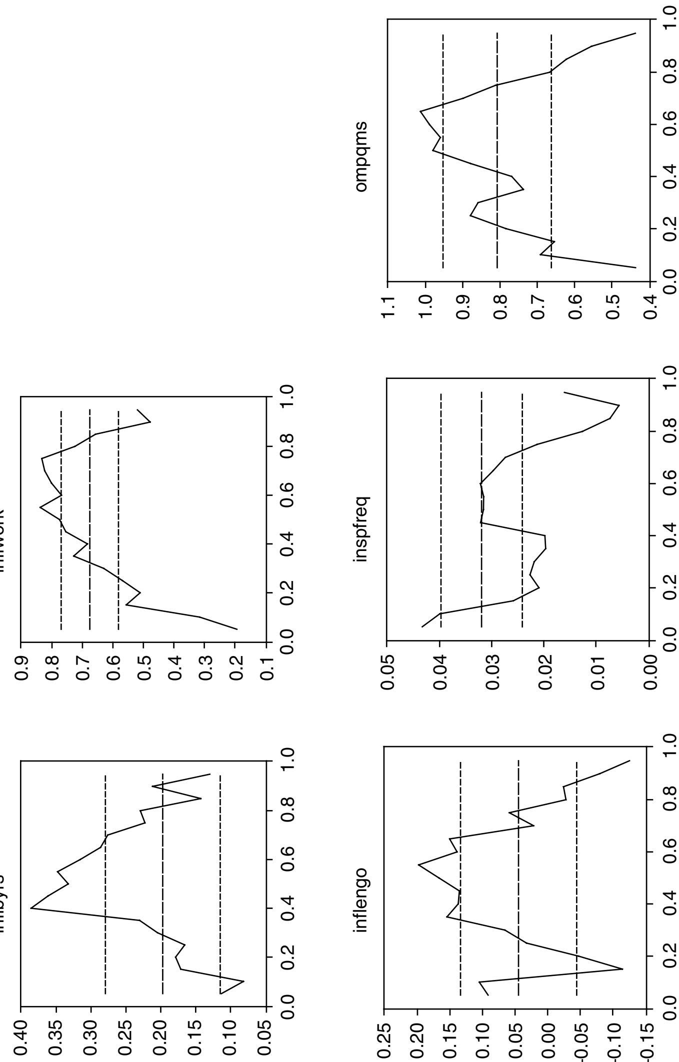
Table 2C.1 Correlations and descriptive statistics

	Mean	SD	1	2	3	4	5	6	7	8
1 *MRKTSCOP*	2.80	1.05	1.00	0.12	0.03	0.12	0.09	0.20	0.04	0.11
2 *FACEMPL*	332.02	855.94	0.12	1.00	0.14	0.07	0.12	0.14	0.05	0.11
3 *FACRDENV*	0.09	0.29	0.03	0.14	1.00	0.04	0.04	0.06	0.07	0.11
4 *FACBPERF*	3.46	0.99	0.12	0.07	0.04	1.00	0.06	0.11	0.01	0.08
5 *INFLPAUT*	2.37	0.65	0.09	0.12	0.04	0.06	1.00	0.37	0.16	0.23
6 *INFLCORP*	2.35	0.69	0.20	0.14	0.06	0.11	0.37	1.00	0.26	0.39
7 *INFLBYRS*	2.09	0.72	0.04	0.05	0.07	0.01	0.16	0.26	1.00	0.27
8 *INFLWORK*	1.95	0.66	0.11	0.11	0.11	0.08	0.23	0.39	0.27	1.00
9 *INFLENGO*	1.71	0.70	0.05	0.08	0.11	0.05	0.34	0.25	0.22	0.32
10 *INSPFREQ*	3.63	6.85	0.09	0.21	0.07	0.07	0.20	0.15	0.00	0.09
11 *OMPQMS*	0.75	0.43	0.18	0.09	0.08	0.08	0.05	0.11	0.13	0.10
12 *IMPNR*	1.90	0.66	0.05	0.12	0.07	0.00	0.09	0.14	0.08	0.09
13 *FRMINTL*	0.12	0.32	0.21	0.05	0.02	0.11	0.10	0.13	0.02	0.12
14 *FRMQUOT*	0.17	0.37	0.17	0.18	0.10	0.10	0.15	0.18	0.02	0.16
15 *VOLAGR*	1.79	0.68	0.03	0.09	0.09	0.04	0.18	0.21	0.25	0.24
16 *TECHASS*	1.71	0.68	0.07	0.04	0.06	0.00	0.22	0.19	0.19	0.22
17 *PRGEMP*	0.21	0.41	0.04	0.06	0.11	0.04	0.15	0.12	0.07	0.15
18 *EMS*	0.39	0.49	0.09	0.17	0.19	0.04	0.02	0.17	0.21	0.18
19 *PERSENV*	0.70	0.46	0.19	0.15	0.13	0.13	0.19	0.26	0.15	0.24
20 *COUNT*	3.63	2.81	0.25	0.25	0.22	0.15	0.17	0.34	0.19	0.33
21 *CERTIF*	0.81	0.39	0.00	0.03	0.02	−0.02	−0.16	−0.06	0.16	−0.03

9	10	11	12	13	14	15	16	17	18	19	20	21
0.05	0.09	0.18	0.05	0.21	0.17	0.03	0.07	0.04	0.09	0.19	0.25	0.00
0.08	0.21	0.09	0.12	0.05	0.18	0.09	0.04	0.06	0.17	0.15	0.25	0.03
0.11	0.07	0.08	0.07	0.02	0.10	0.09	0.06	0.11	0.19	0.13	0.22	0.02
0.05	0.07	0.08	0.00	0.11	0.10	0.04	0.00	0.04	0.04	0.13	0.15	−0.02
0.34	0.20	0.05	0.09	0.10	0.15	0.18	0.22	0.15	0.02	0.19	0.17	−0.16
0.25	0.15	0.11	0.14	0.13	0.18	0.21	0.19	0.12	0.17	0.26	0.34	−0.06
0.22	0.00	0.13	0.08	0.02	0.02	0.25	0.19	0.07	0.21	0.15	0.19	0.16
0.32	0.09	0.10	0.09	0.12	0.16	0.24	0.22	0.15	0.18	0.24	0.33	−0.03
1.00	0.08	0.00	0.03	0.08	0.10	0.27	0.33	0.15	0.00	0.13	0.16	−0.10
0.08	1.00	0.05	0.12	0.06	0.13	0.10	0.06	0.08	0.09	0.16	0.24	−0.04
0.00	0.05	1.00	0.12	0.10	0.10	0.06	0.02	0.06	0.26	0.22	0.26	0.27
0.03	0.12	0.12	1.00	0.03	0.10	0.06	−0.02	0.08	0.23	0.17	0.25	0.12
0.08	0.06	0.10	0.03	1.00	0.27	0.04	0.03	0.07	0.11	0.12	0.19	0.00
0.10	0.13	0.10	0.10	0.27	1.00	0.03	−0.01	0.12	0.19	0.20	0.32	−0.11
0.27	0.10	0.06	0.06	0.04	0.03	1.00	0.48	0.11	0.07	0.11	0.18	0.05
0.33	0.06	0.02	−0.02	0.03	−0.01	0.48	1.00	0.13	−0.06	0.03	0.05	−0.08
0.15	0.08	0.06	0.08	0.07	0.12	0.11	0.13	1.00	0.18	0.20	0.24	−0.13
0.00	0.09	0.26	0.23	0.11	0.19	0.07	−0.06	0.18	1.00	0.41	0.64	0.49
0.13	0.16	0.22	0.17	0.12	0.20	0.11	0.03	0.20	0.41	1.00	0.59	0.06
0.16	0.24	0.26	0.25	0.19	0.32	0.18	0.05	0.24	0.64	0.59	1.00	0.22
−0.10	−0.04	0.27	0.12	0.00	−0.11	0.05	−0.08	−0.13	0.49	0.06	0.22	1.00

APPENDIX 2D QUANTILE REGRESSION COEFFICIENTS FOR COMPREHENSIVENESS OF ENVIRONMENTAL MANAGEMENT SYSTEM

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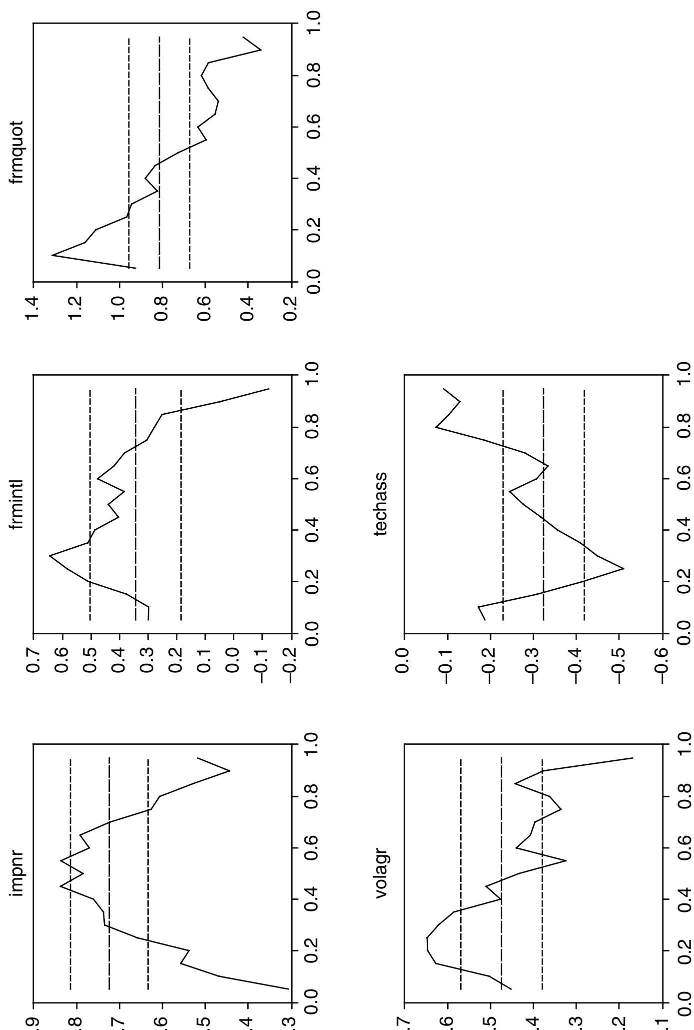
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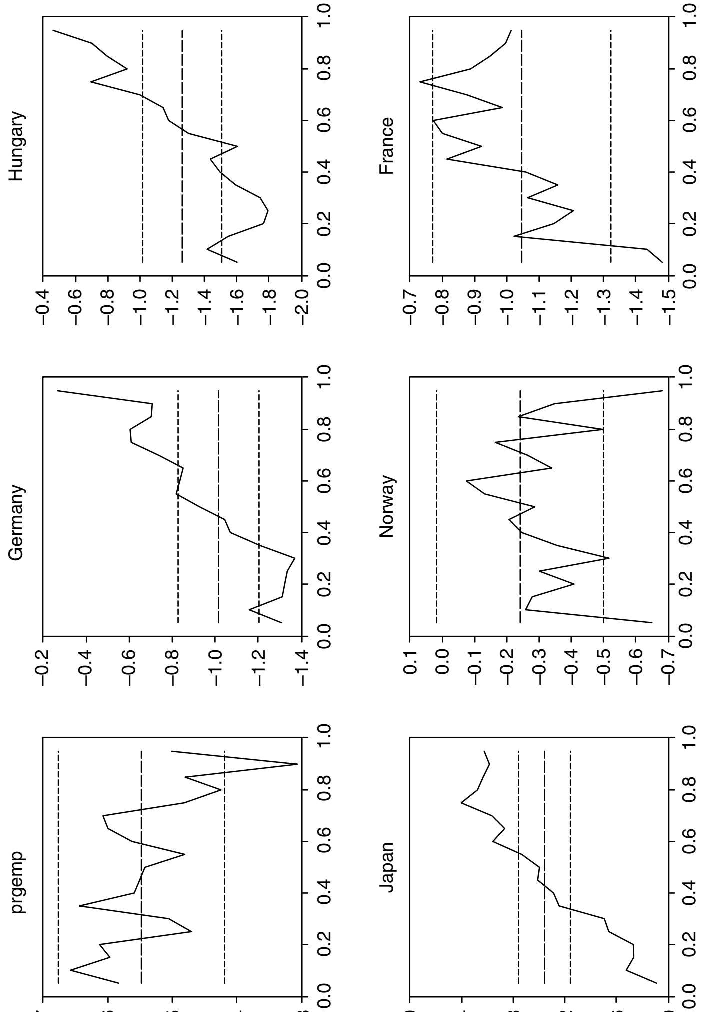
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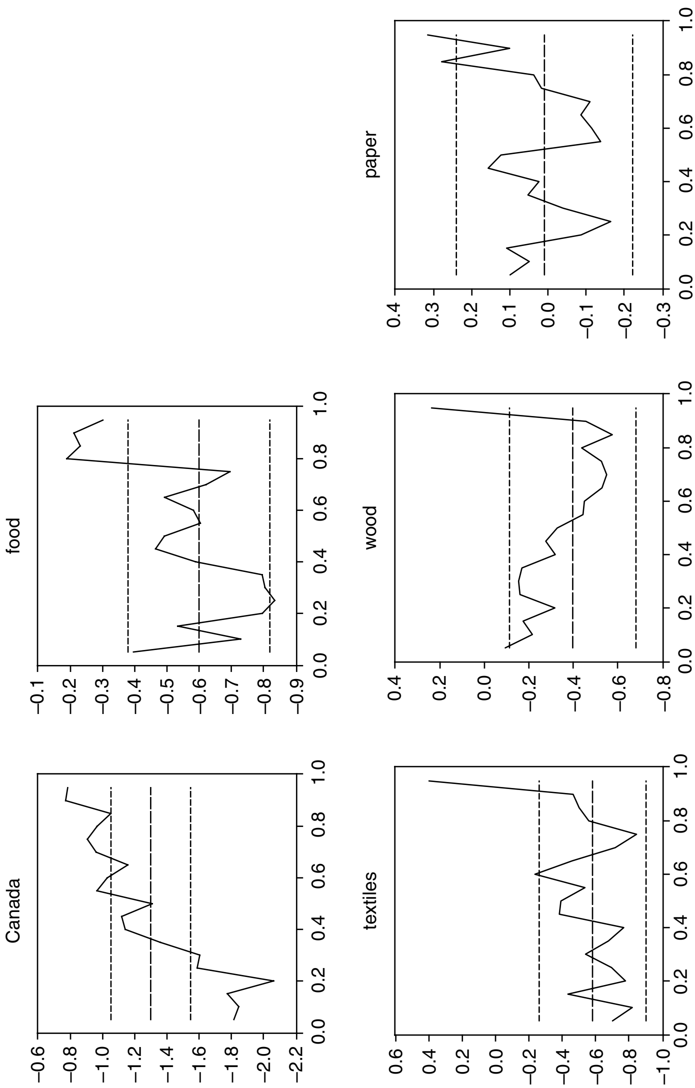

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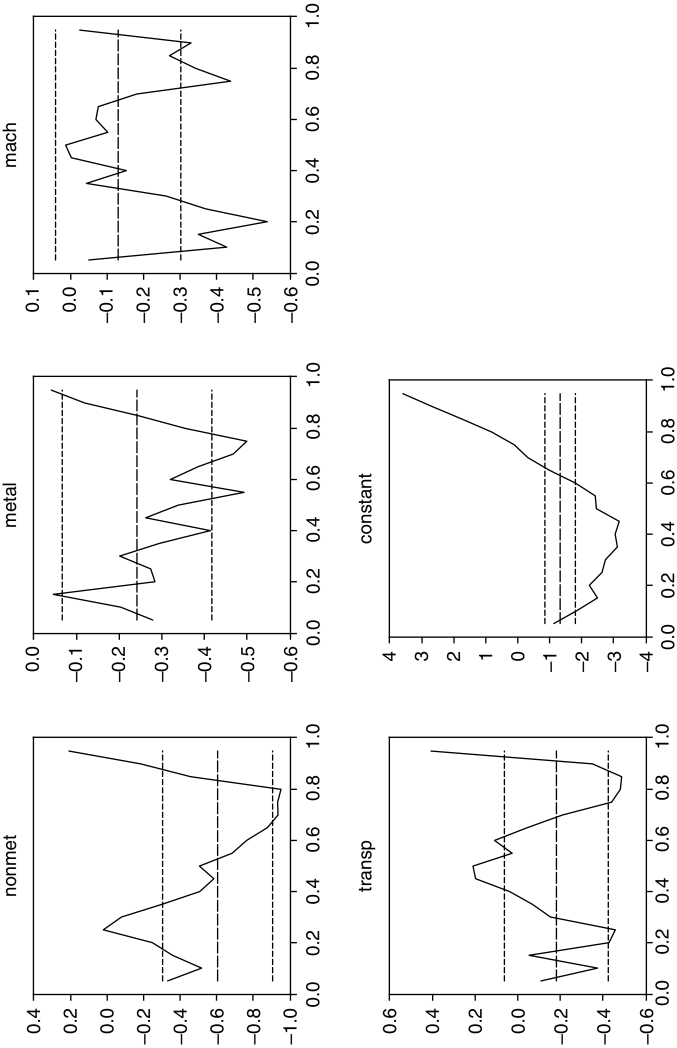
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3. 'Many a slip 'twixt the cup and the lip': direct and indirect public policy incentives to improve corporate environmental performance

Nick Johnstone, Matthieu Glachant, Céline Serravalle, Nicolas Riedinger and Pascale Scapecchi

I. INTRODUCTION

Recent empirical and theoretical work has highlighted the importance of an understanding of the firm's decision-making procedures and organizational structure when designing and implementing public environmental policies. Indeed, most assessments of the different public environmental policy often treat the internal workings of the firm as a 'black box', assuming that firms will respond in a predictable manner. Two recent policy developments in OECD countries justify a focus on organizational issues internal to firms:

- The growth in the use of information-based measures and voluntary approaches at the expense of mandatory policies such as economic instruments and direct regulation.
- An increased interest in, and the provision of incentives for, the implementation of environmental management systems and tools within the firm.

The former development is certainly partly associated with the political difficulties associated with the introduction of strict mandatory policies, whether economic instruments or direct forms of regulation. However, it is perhaps also attributable to a belief that there are opportunities for realizing environmental improvements in a manner which is also in the commercial interest of the affected firms. Whether or not such opportunities are significant enough to warrant a re-examination of existing policy frameworks remains a subject of considerable controversy.

Similarly, the latter development is perhaps explained by a belief amongst public authorities (and others) that firms are not recognizing at least some cost-effective abatement opportunities and that by encouraging the adoption of EMSs, governments can play a role in helping them to identify such opportunities. More generally, the efficacy of policies designed to encourage improved environmental management is predicated upon a rich understanding of the firm's organizational characteristics and strategic behaviour. However, such organizational issues are not usually reflected in discussions of the relative merits of different policy instruments

This chapter provides an overview of work undertaken using the OECD database on the assessment of the determinants of a firm's reported environmental performance. This includes an examination of the role played by the general structural characteristics of the firm. In addition, the public policy framework is examined. This includes both the stringency of public policy and the frequency of inspections, as well as the specific type of policy instrument introduced. In particular, it is interesting to examine whether mandatory policy measures (direct regulations and market-based instruments) have greater influence than voluntary and information-based policy approaches. And finally, the introduction of environmental management systems and tools can also potentially contribute to improved environmental performance. In the event that the introduction of environmental management systems have positive impacts, it is then necessary to examine whether or not targeted incentives to introduce environmental management systems should be encouraged by public policy, and precisely how this is best undertaken. In particular, a further aspect is that some targeted measures to encourage firms to implement environmental management systems, such as the granting of 'regulatory relief', may adversely affect environmental performance.

Given these complex interrelationships between the determinants of environmental performance and the adoption of an EMS, a proper understanding of the policy determinants of the facility's environmental performance requires an investigation of both the direct effects of different variables on environmental performance, and the indirect effects which arise through the decision as to whether to implement environmental management systems and tools. There are, therefore, three questions which need to be addressed:

- What policy and economic variables affect environmental performance through their direct impact on the firms' incentives to undertake pollution abatement?

- Does the implementation of an EMS affect environmental performance, either by reducing the costs or increasing the benefits of such investments?
- What public policy and economic variables have significant impacts on the facility's propensity to adopt an EMS?

Of course, when considering these questions we need to consider both general environmental policies (direct regulations, market-based instruments, voluntary agreements, and so on) and targeted EMS-promoting policies (financial support, technical assistance, regulatory relief, and so on) as well as general environmental policy variables such as the perceived strictness of the regulatory regime and the reported frequency of inspections.

In order to assess these issues in a credible manner, a significant methodological problem must be overcome: the presence of an EMS may be endogenous with respect to environmental performance. If only a certain type of firm (and especially the most efficient ones) implements an EMS, naive estimation methods will overestimate the efficiency of EMS, given the fact that more efficient firms choose to implement them, and that some of the other factors which characterise 'efficient' firms may be mistakenly attributed to the mere presence of an EMS. In order to solve the problem, we use simultaneous equations techniques to estimate environmental performance.

In a first section, we present a conceptual framework to understand the facility's choice of performance level and of the adoption of an EMS. In the second section, we discuss methodological approaches applied in order to overcome problems of endogeneity and selection. In the third and fourth sections, we present the data and the estimation methods implemented. And finally in the fifth section of the report our results are presented.

II. LITERATURE REVIEW

While there are a large number of studies based upon informal and anecdotal evidence of the links between firm characteristics, public policy frameworks, environmental management and environmental performance, there is surprisingly little formal empirical literature. In this section the available empirical evidence will be reviewed. This will include a review of the evidence on the relationship between firm characteristics, public policy, environmental management and environmental performance.

Firm Characteristics and Environmental Performance

Due to the importance of exogenous firm characteristics (firm size, fuel type, product diversification, and so on) there can be as much variation in environmental performance within a sector as there is for similar plants in different sectors (see Streitweiser 1994 for some empirical evidence from the United States). Identifying the links between such characteristics and environmental performance is key to successful environmental policy design. Firstly, this will help public authorities target scarce resources toward areas where it can be of the greatest use. Secondly, it will help public authorities enforce regulations more efficiently. Thirdly, it may help policy makers design policies differently for different segments of the economy.

The empirical literature which does exist hypothesizes a number of relationships between various 'exogenous' firm characteristics and environmental performance (see Johnstone 2001 for a fuller discussion). A number of issues are thought to be particularly important:

- Firm size – presumed to be positive due to visibility (and thus probability of enforcement and strength of community pressures), as well as economies of scale in environmental investments.
- Capital stock turnover – presumed to be positive due to the 'cleaner' nature of many newer technologies relative to older technologies.
- Exposure to international markets – presumed to be positive due to economies of standardization and the need to meet standards of most stringent market.
- Geographical origins of capital – dependent upon the relative stringency of domestic regulations compared to other countries.
- Source of equity – presumed to be positive for firms with stock exchange listings due to the environmental demands of equity markets.
- Capital availability – presumed to be positive for firms with internal sources of funds due to the capital costs of investments in environmental improvements.[1]
- Public authorities vs. private firms – presumed to be negative for public authorities due to a lower probability of enforcement and existence of soft budget constraints which discourages material efficiency.[2]
- Diversity of product lines – presumed to be negative due to diseconomies of scope in investment in environmental improvements.
- Proximity to final consumers – presumed to be positive due to the importance of environmental demands of final consumers.

As noted, the empirical evidence for these relationships is surprisingly thin on the ground, with very few studies looking systematically at the relationship between firm characteristics and environmental performance. A number of studies do so in a descriptive manner (for example, UNCTAD 1993), reporting on the degree of correlation between some of these factors and environmental performance.

However, these results are not of particular value for policy makers since there is such a high degree of correlation between the various explanatory factors analysed. For instance, large firms tend to have greater access to capital, tend to be more exposed to international markets and are more likely to have public shareholdings. Thus a high degree of correlation between environmental performance and any of these factors may say very little about the actual nature of the relationship in question. The true relationship (as revealed in multivariate analysis) may be much stronger or weaker, and may even be opposite in direction to that assumed.

Moreover, it is very difficult to define an appropriate variable for environmental performance. For instance, in previous empirical work, the following indicators have been used: visible evidence of abatement efforts, reported emission rates, self-assessed environmental performance, regulatory compliance and involvement in a voluntary environmental programme. All of these proxies have some methodological problems. Nonetheless, the evidence is revealing and of interest. Table 3.1 provides a summary of the general results, drawing upon results from a large number of empirical studies[3] (Johnstone 2001 provides a fuller discussion).

Table 3.1 Firm characteristics and environmental performance

Characteristic	Hypothesised relationship	Evidence
Firm size	Larger -> improvement	Generally supported
Capital vintage	Newer -> improvement	Not supported
Trade ratio	Highly traded -> improvement	Weakly supported
Investment source	Foreign -> improvement	Not supported
Source of equity	Public shareholdings -> improvement	Generally supported
Capital availability	Internal -> improvement	Generally supported
Institutional characteristics	Private firm -> improvement	Generally supported
Proximity to final consumers	Closer -> improvement	Weakly supported
Diversity of product lines	Specialization -> improvement	Generally supported

Public Policy and Environmental Performance

One of the first studies on the links between public environmental policy and environmental performance was an analysis of transnational corporations based in the United States. In the study, Levy (1995) finds weak support that regulatory pressures (as reflected in the number of reported 'Superfund sites') had a negative influence on Toxic Releases Inventory (TRI) emissions. However, the small size of the sample (less than 100), and the informal nature of the estimation, cast doubt on the reliability of the results.

Looking specifically at the question of whether inspections have had an influence on environmental performance, Magat and Viscusi (1990) undertook a study examining the determinants of TSS and BOD emissions from the American pulp and paper sector. They found that inspections reduced the level of emissions by 20 per cent. In a study of the Canadian pulp and paper sector, Laplante and Rilstone (1996) find the even more striking result that the mere threat of inspection can reduce emissions significantly.

Gray and Shadbegian (1997) analyse the relationship between regulatory factors and the environmental characteristics of technology choice amongst pulp and paper firms in the United States. Regulatory stringency (as reflected in a variety of different proxy variables) leads firms to invest in those technologies which are less damaging with respect to air and water pollution. For instance, mechanical pulping is negatively affected by the presence of strict air pollution regulations and sulphite pulping is negatively affected by the presence of strict water pollution regulations.

In their study of the Mexican food, chemicals, non-metallic minerals and metal sectors Dasgupta et al. (2000) found that facilities which had been previously inspected were significantly 'cleaner' (as reflected in self-reported compliance) than their counterparts which had never been inspected. Self-reported data on the perceived influence of regulatory rules also has a generally positive influence on compliance, although the results in this case are more ambiguous.

Analyses of the effects of alternative policy instruments (rather than regulatory stringency *per se*) are rare. In a comprehensive analysis of the chemical sector's Responsible Care Program, King and Lenox (2000) find no evidence that the programme positively influenced the sector's environmental performance in the United States, as reflected in TRI data. Indeed, there is some evidence that the rate of improvement of programme members is slower than that of non-members.

In a review of emissions of sulphur dioxide from the French manufacturing sector, Riedinger and Hauvy (2005) find that the environmentally related tax imposed (the *taxe parafiscale sur la pollution atmosphérique*) has no discernible impact on the technology of air pollution abatement. This result is due to the fact that co-existing regulatory instruments impose marginal abatement costs in excess of the tax level, thus nullifying the incentive effects of the tax.

Anton et al. (2004) look at the effects of two measures of policy stringency (inspections and number of 'Superfund' sites) on toxic emissions and hazardous air pollutants amongst American manufacturing plants. Surprisingly, they do not find a significant direct effect, but do report a potential indirect effect through incentives on the adoption of environmental management practices (this finding is further discussed below).

A number of studies have also been undertaken in non-OECD countries. For instance, in a survey of 121 manufacturing plants (chemicals, food and beverages, textiles and wood processing sectors) in Indonesia, Aden and Rock (1999) estimated the effects of the frequency of government inspections and the number of warning letters issued on the probability of having installed pollution control equipment and on pollution control expenditures. They found significant and positive effects in the former case, but not the latter case.

In a study of almost 10 000 firms in Brazil, Ferraz and Seroa da Motta (2002) find that regulatory pressures (as reflected in data on fines, warnings and environmental agency employees by municipality) have a significant and positive impact on the likelihood of firms having invested in environmental technologies. These results hold up under a wide variety of econometric specifications.

In a study conducted in Zhenjiang in China Dasgupta et al. (1996) look at the effect of both pollution charges and inspection rates on water pollution (discharges of Total Suspended Solids – TSS and Chemical Oxygen Demand – COD) and air pollution (emissions of Total Suspended Particulates – TSP). Interestingly they find that the inspection rate is a better determinant of the firm's environmental performance than the value of any environmental levies charged. Indeed, the latter does not have a statistically significant effect.

Environmental Management and Environmental Performance

Do environmental management systems and tools actually result in improved environmental performance? There is much anecdotal evidence in this area, with many studies citing cases in which individual firms have reported the benefits of introducing particular environmental strategies (see Johnstone 2001 for a review). Thus, it is widely reported that environmental auditing, environmental management systems, and other tools have played a decisive role in bringing about improved environmental performance.

However, many of the existing studies draw their conclusions on the basis of small samples, and do not distinguish between the role of EMSs themselves and other factors which lead to improved environmental performance, but which may be highly correlated with the presence of an EMS. This can give a very misleading perception of the true role of environmental management practices in bringing about changes in environmental performance. There is, therefore, very little credible and reliable empirical evidence in this area. However, a small number of studies provide some evidence.

In the aforementioned study of Mexican manufacturing firms, Dasgupta et al. (2000) undertook an analysis in which they evaluated the importance of the presence of various environmental management and policy indicators on reported environmental performance (reflected in the degree of compliance relative to the regulatory standard). They found that three factors had significant and positive effects: the number of steps completed in ISO 14000 EMS; a dummy variable reflecting whether or not environmental training had been given to non-environmental workers; and a dummy variable reflecting whether or not environmental managers were assigned to other work in the firm.

In their survey of Italian firms, Siniscalco et al. (2000) found that between the years 1994 and 1997 reported SOx and NOx pollution rates fell more for firms with environmental management tools (compensation schemes, audits and award schemes) than those without such schemes. In multivariate analysis they found that the quality of the information provided in environmental reports had a negative (that is, beneficial) and significant effect on pollution rates. Audits, compensation schemes and award programmes also had a beneficial effect, but this arose indirectly through their effect on financial performance.

In addition, in an analysis of the European Business Environmental Barometer survey (see Johnstone et al. 2004) it was found that the presence of a certified EMS (EMAS or ISO) had a positive effect on the number of environmental initiatives undertaken by a firm. Indeed, and rather surprisingly, the coefficient reflecting whether or not an environmental management system was certified was more significant than any of the other variables, including national and sectoral dummy variables.

As noted above, Anton et al. (2004) used instrumental variables estimation techniques to examine the role of a variety of environmental management practices on reported environmental performance. Interestingly, they find that such measures had a positive role, and that their importance was particularly significant for those firms which were originally the worst environmental performers. They also found that environmental management practices encouraged the introduction of changes in production process rather than end-of-pipe solutions (see also Labonne and Johnstone 2006).

Conversely, Levy's (1995) analysis of the UNCTAD Benchmark Survey does not find supporting evidence. American-based firms which produced annual environmental reports, which had company-wide environmental policies in place, and which had standardized procedures, for environmental practices, were no more likely to have reduced their emissions of toxins than other firms. Other studies have, however, found some evidence that environmental reporting does result in reduced emissions (see, for instance, Konar and Cohen, 1997). However, most of these studies are based upon public environmental registries, where credibility issues are less important.

Originality of the Study

Compared to the existing literature, our study presents a number of original features. The first is the database which covers manufacturing facilities from seven OECD countries. Therefore, the results are not country-specific, but allow for a comparison of a rich variety of different economic and policy contexts prevailing in the different countries. Moreover, small and medium-sized enterprises are well represented, a feature which is not common.

Second, most of the previous studies focus on one policy variable – policy stringency (Gray and Shadbegian 1998), inspections (Laplante and Rilstone 1996; Magat and Viscusi 1990; Dasgupta et al. 2000), fines and number of warnings (Ferraz and Seroa da Motta 2002), a given voluntary programme (King and Lenox 2000) or a combination of policy variables – a combination of tax and a standard (Riedinger and Hauvy 2005), inspections rates and pollution charges (Dasgupta et al. 2000). By contrast the spectrum of policy variables investigated in our study is very large: several types of general policy instruments, the frequency of inspections, the policy stringency, but also specific policy measures encouraging the adoption of an EMS (for example, regulatory relief).

Third, we assess the impacts of policy variables on both EMS adoption and environmental performance, using simultaneous estimation techniques. This allows for the investigation of both the direct effects of the policy variables on environmental performance, and also the indirect effects they may have on performance through their influence on EMS diffusion. This latter point is significant because some policy variables can impact upon both decisions (management and performance), but may do so in strikingly different ways. Moreover, the role that EMSs may play with respect to environmental performance is likely to depend upon the motivation for its introduction.

However, a significant constraint on the study arises from the use of a single cross-section rather than longitudinal data. Given that the effects of particular policy and management variables will have complicated dynamic impacts on a firm's environmental performance and actions, this limitation must be borne in mind. Moreover, there is significant potential for selection and strategic bias in a survey of this kind, and these issues were discussed in Chapter 1. As will be discussed in the section which follows, the nature of the estimation methodology is such that these problems are addressed to the extent possible.

III. A FRAMEWORK TO ANALYSE THE ABATEMENT AND MANAGEMENT DECISIONS

In this section, we model the facility's decision to implement environmental management tools and its decision to improve environmental performance in order to illustrate the mechanisms through which management procedures can improve environmental performance. We use a cost–benefit framework similar to that developed in Dasgupta et al. (2000).

Choice of the Target Level of Environmental Performance

As the general aim of the study is to identify the determinants of environmental performance, we consider first the facility's performance-setting decision. For ease of exposition, environmental performance is associated with specific levels of pollution abatement. On this basis we can derive the curves of the facility's marginal benefits and costs for increasing levels of abatement (see Figure 3.1).

Benefits primarily arise from policy factors (such as reduced expenditures on environmentally related taxes, or avoided costs that could be incurred in the case of observed non-compliance). Other factors such as firm image and improved community relations may also play a role in shaping this function. Marginal benefits are assumed to be decreasing. This may be explained by decreased probabilities of being caught in a position of non-compliance, as well as decreased penalties associated with being non-compliant.

In addition, we make the usual hypothesis that marginal costs of abatement are rising. This arises from the standard engineering economics of abatement costs which emphasizes the existence of diminishing returns in abatement opportunities – the low-hanging fruit are picked first, with very high costs for the removal of the final residual emissions. Empirical evidence from Hartman et al. (1994) supports this assumption.

The facility sets its level of environmental abatement which maximizes its net benefits and thus equates marginal costs and benefits at A(0). Note

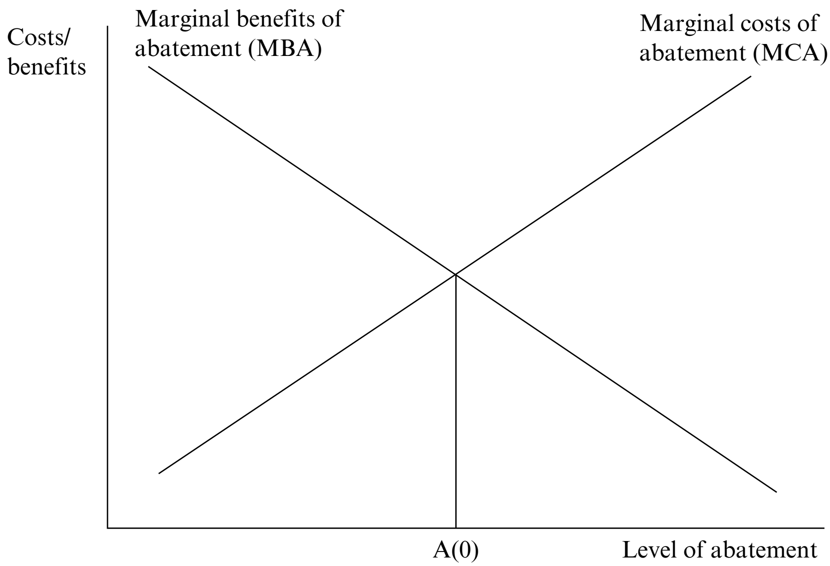

Figure 3.1 Selection of the level of environmental performance

that for heterogeneous facilities subject to heterogeneous external pressures and market conditions, the equilibrium abatement level will differ. For instance, if economies of scale are important, the marginal cost curve will be lower for large firms.

We can use this figure to illustrate how public policy variables or management variables affect the equilibrium performance A(0). For instance, we can consider the possible impact of an environmental management system on A(0). Initially, it is assumed that some of the elements associated with the implementation of an EMS helps the facility to identify (that is, environmental accounting) and act upon (that is, environmental training for employees) cost-effective opportunities to bring about improved environmental performance. Therefore, the introduction of an EMS leads to a downward shift of the marginal abatement cost curve as indicated in Figure 3.2. In the end, the introduction of the EMS induces an increase in the level of abatement up to A(1).

Alternatively, the public policy framework can be examined. For instance, an environmental tax raises marginal abatement benefits since abating emissions reduces tax payments, as shown in Figure 3.3. As a result, the abatement level increases from A(0) to A(1). The same holds for direct forms of regulation. While not usually described as a continuous function, if the probability of enforcement and the associated penalties

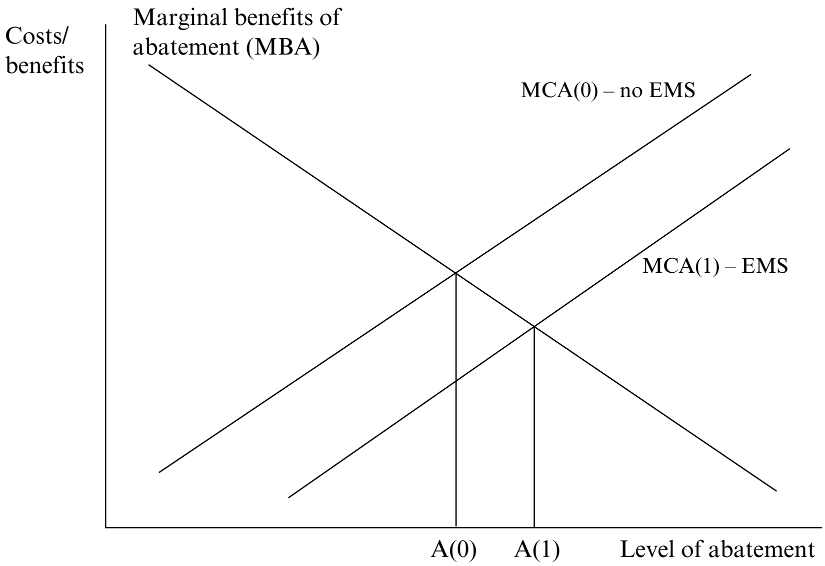

Figure 3.2 The impacts of environmental management on abatement

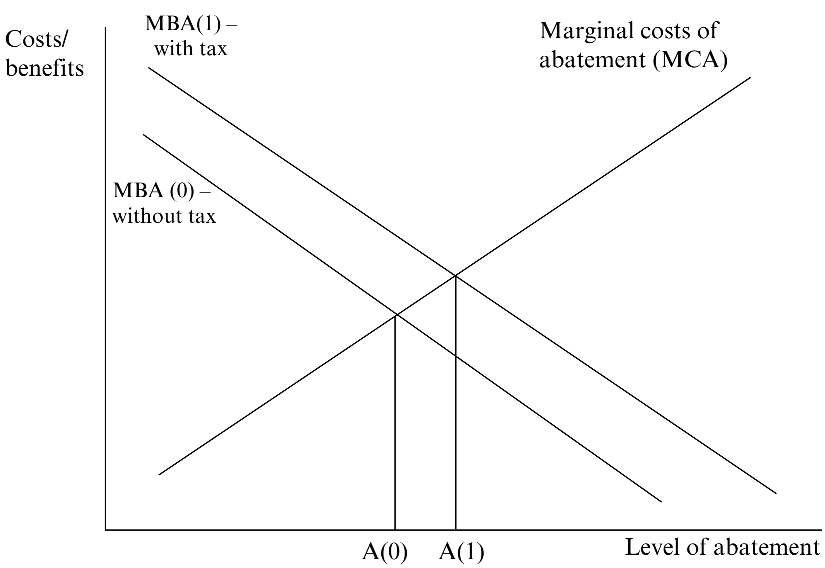

Figure 3.3 The impacts of public policy on abatement

vary negatively with the level of abatement then the effect would be comparable. Moreover, the other benefits associated with abatement (that is, improved community relations, access to capital, market perceptions, and so on) are likely to vary continuously with abatement levels.

The Decision to Adopt an Environmental Management System

As noted above, the presence of environmental management systems and tools in a facility is potentially important in determining the facility's environmental performance. However, the facility's decision to introduce environmental management systems and tools is itself a reflection of the relative benefits and costs of introducing such measures.

For ease of exposition, we assume that the comprehensiveness of the management systems and tools in a given facility can be described as a continuous variable. For instance, one can view this variable as reflecting the number of management tools adopted or the resources devoted toward such tools. Alternatively it may be the resources devoted toward their implementation. For instance, Kolk (2000) has estimated the cost of establishing an EMS as US$25 000 to US$100 000 per facility, as well as significant ongoing annual costs. According to one EPA official, transaction costs for a large firm can be as great as US$1 million (Potoski and Prakash 2005). Then, we can draw the curves of the facility's marginal benefits and costs for increasing levels of environmental management (see Figure 3.4).

Benefits arise from the role that environmental management plays in bringing about improved environmental performance in a cost-effective manner. It may also play a signalling role in product or financial markets, informing stakeholders of facility qualities. Marginal benefits from increased investments in environmental management are assumed to diminish. The underlying justification may be that the facility implements the tools with the highest 'yield' first. Symmetrically, marginal costs are assumed to increase since the facility implements the least costly management tools first. The facility sets its level of environmental management at M(0) by equating marginal costs and benefits.

What are the possible impacts of various policy variables on the decision concerning the level of environmental management implemented? Looking first at policies which target abatement levels directly (such as direct regulation, economic instruments, and so on), the choice of environmental policy measure may affect the propensity to introduce an EMS. For instance, it may be foreseen that market-based instruments, by allowing for 'flexible' responses on the part of facilities, will encourage facilities to adopt an EMS by raising the marginal benefits of the EMS. Well-designed performance standards should have the same effect since they allow for flexible responses.

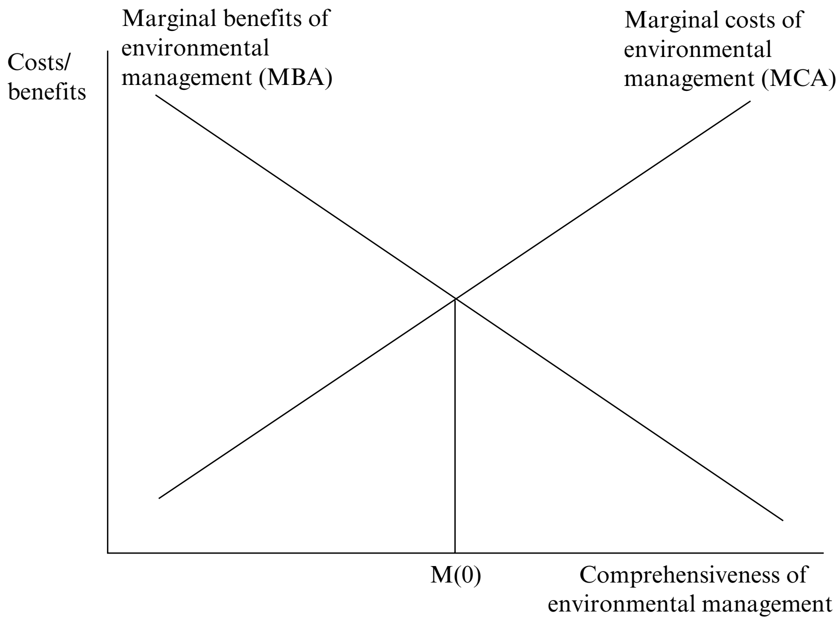

Figure 3.4 The decision to adopt an EMS

The adoption of an EMS will affect the environmental performance decision since the benefits of EMS partly consist of reduced abatement costs (the EMS facilitates the identification of cheaper abatement options). In the end, the market-based instrument will increase environmental performance indirectly through its effect on EMS adoption (a shift in the MAC curve), as well as through its direct effect on performance (shifts along the MAC curve).

Analogously, it may be surmised that more prescriptive technology-based standards will result in fewer benefits from environmental management since the value of the information generated (that is, via environmental accounting) and the mechanisms by which such information can be acted upon (that is, training policies) is correspondingly lower. Thus, the adoption of an EMS is not likely to generate as significant benefits for the firm under direct regulations which are more prescriptive in nature and thus give firms much less flexibility in their abatement strategy. There is little benefit in identifying cost-effective abatement opportunities if the regulatory regime restricts your options (see Coglianese and Nash 2001b).

However, if EMSs are seen by managers as primarily measures to ensure that a firm is in compliance, the difference in incentives for their adoption provided by flexible and prescriptive policy instruments may be less apparent. For instance, by providing information on the regulatory environment and on the status of the firm's degree of compliance, there may be little difference in the effects that flexible and prescriptive measures have on the marginal benefits function.

Similarly, the effect of policies which target environmental performance indirectly via incentives for environmental management can be examined. On the one hand, a distinction between supply-side and demand-side policies is helpful. For instance, on the supply side, the provision of financial or technical assistance for the introduction of an EMS results in a shift (down) of the marginal cost curve of Figure 3.3. Analogously, a demand-side policy which provides public recognition or public procurement preferences for firms which have introduced an EMS will shift the marginal benefit curve up, also increasing the equilibrium level of environmental management.[4]

On the other hand, if well designed, both of these types of policies should only impact upon environmental performance through the effect they have on the environmental management decision. They should not give rise to any direct effects on the environmental performance decision. However, as will be discussed, a third category of EMS-promoting policy (one which provides different forms of regulatory relief) may have more subtle effects. It will have similar consequences for the EMS decision as a demand-side policy. In effect, it shifts up the marginal benefits curve. However, the effects on environmental performance are more ambiguous, and may even be negative under certain conditions. This is described below.

The Links between Environment Management and Performance Decisions

The last point concerns the transmission mechanism from the equilibrium environmental management (EM) level to the abatement level, an issue which has already been touched upon – that is, how great is the downward shift in the abatement cost curve associated with an increased level of environmental management. If we consider an axis representing the environmental management level and another for the choice of abatement level, we posit that, for increased levels of environmental management, an optimizing facility will have higher levels of abatement.

The global mechanism from a change in EM marginal cost or benefit curve to the performance target choice is presented in Figure 3.5. In this case, the effect of a policy reducing the cost of increasing the comprehensiveness of environmental management (or introducing an EMS) is considered. As the level of environmental management increases, the level of abatement will be affected as explained in section A – that is, the marginal abatement cost curve (MCA) will shift down from MCA(0) to MCA(1), and the equilibrium level of abatement will increase from A(0) to A(1). The

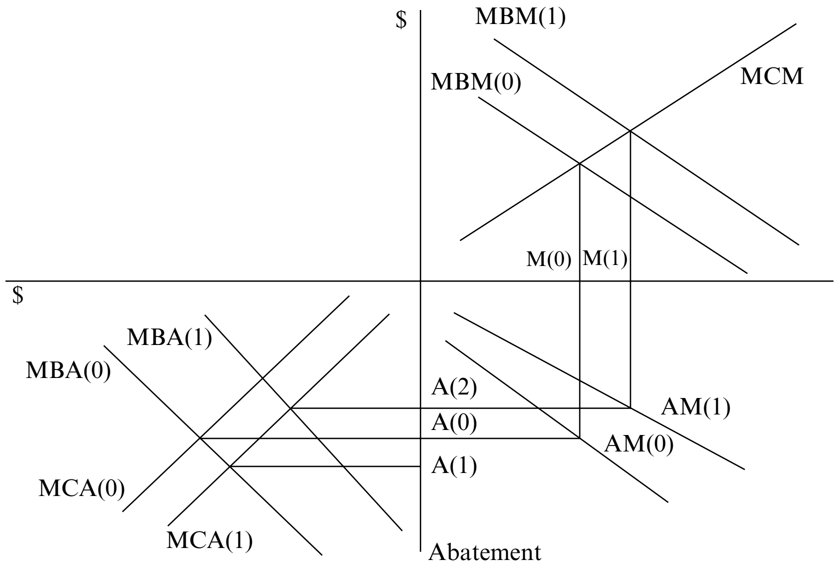

Figure 3.5 The links between management decisions and performance

slope of the AM curve – which merely traces out the relationship between the equilibria in the top-right management quadrant and the bottom-left abatement quadrant – will transmit more or less strongly the effects of an increase in environmental management to environmental performance.

How can we explain situations where facilities increase their level of environmental management, but do not achieve higher levels of environmental performance? For reasons we are going to develop below, some policy incentives may actually result in a shift of marginal benefits of abatement curve down (MBA(1)). This will certainly reduce the overall benefits of the policy – that is, A(1) is less than in cases where there is no effect on the marginal benefits of abatement. Moreover, depending upon the relative importance of the different effects this can lead to a situation where abatement is actually less than prior to the introduction of the policy (A(2) < A(0)).

In effect, the AM curve has shifted to (AM(1)) – that is, the curve is not exogenously given, but is affected by the nature of the incentives introduced to encourage the adoption of an EMS. A key question is, therefore, whether the relationship between environmental management and performance can be assumed to be independent of the incentives provided by public policy makers. For instance, if governments seek to target environmental performance indirectly via environmental management, the nature of this relationship pre- and post-intervention is key.[5]

IV. THE NECESSITY TO ESTIMATE SIMULTANEOUSLY THE ENVIRONMENTAL MANAGEMENT AND PERFORMANCE DECISIONS

As noted above, the aim of the study is to identify the determinants of facility's environmental performance with a special focus on EMS on the one hand, and public policy variables on the other hand. The interplay between these two categories of variables is considered. More specifically, we investigate two questions:

- What public policy variables have significant impacts on the facility's propensity to adopt an EMS or another management tool? Of course, we need to consider specific EMS-promoting policies, but also general environmental policy variables such as the perceived strictness of the regulatory regime, the frequency of inspections and the nature of the policy instruments.
- What public policy variables have a significant effect on environmental performance? We seek to identify both direct effects and indirect effects. Indirect effects indicate the role that policy variables have in promoting EMS, which are posited to lead indirectly to changes in environmental performance.

Answering these questions raise two methodological difficulties. The first problem is associated with the potential endogeneity of decisions concerning the level of EMS with respect to decisions concerning the level of environmental performance. The second concerns the distinction between the direct versus indirect effects of policy variables. Together, these two factors may result in cases in which policies have unintended consequences. The solution is common to both problems: we need to estimate the EMS and the performance decisions simultaneously.

Endogeneity of EMS and Self-Selection

This issue can be explained using an intentionally oversimplified hypothetical case. Assume that there are two facilities, one denoted 'Green' and the other one 'Brown'. Neither of them has an EMS in place at the outset. Green has historically had very good environmental performance and very good environmental management practices in place for years for various reasons (for example, the existence of an ambitious environmental corporate policy). It could be considered to be a leader in the environmental field. Brown is just the opposite. It has continuous problems of non-compliance, and environmental management efforts are historically very low. In summary, it is a laggard.

Accordingly, assume that Green adopts an EMS while Brown does not. If we observe the differences in environmental performance after the EMS adoption decision, we observe that Green has a much better performance than Brown. Therefore, we can be tempted to conclude that the introduction of an EMS is very effective in inducing abatement. However, this conclusion may be false. In fact, we do not know whether Green's performance is due to the EMS as such, or rather due to the fact that Green has already had good management practices before the introduction of the EMS. Put differently, we do not know which of these two statements is correct:

- Green has good environmental performance, and this is because it has implemented an EMS; or
- Green has adopted an EMS because it generally has good management practices and good performance prior to the introduction of the EMS.

It is said to be a problem of self-selection because its source is the fact that each facility self-selects whether it adopts an EMS or not. In turn, self-selection creates an econometric problem of endogeneity. Endogeneity arises because the variable indicating whether the facility is Green or Brown is unobserved in the database. We do not know what the management practices and performances were before the introduction of the EMS. As a result, we get a biased estimate of the impact of the variable EMS. More precisely, as being Green is positively correlated with EMS, we overestimate the coefficient of EMS.

Note that the variable describing whether a facility is Green or Brown is just one example. One can imagine many other unobserved factors that affect the propensity to adopt an EMS. If these factors are also positively correlated with the performance (and they are unobserved), we will overestimate the effect of EMS on performance. For instance, Coglianese and Nash (2001a) argue that the presence of an EMS may reflect broader managerial commitment to environmental concerns, and that many studies may incorrectly attribute improved environmental improvements to the introduction of an EMS, rather than this broader commitment level. The fact that those factors correlated with performance are not observed is key in the reasoning. If they were known, we would simply solve the problem by including them in the performance equation as control variables.

Econometrically, the solution to model this situation correctly consists in estimating simultaneously the performance equation and the management equation. Using instrumental variable estimation, endogenous regime-switching models or other simultaneous equations techniques are adapted to do precisely that. The key property of these techniques is to take into account the existence of a correlation between the error terms of the performance and the management equation. The estimation of this correlation is equivalent to assuming that a hidden variable (a binary variable indicating whether the firm is a leader or a laggard) might have an impact that we should take into account.

Direct and Indirect Effects of Policy Measures

In many cases the direct and indirect effects of policy measures on environmental performance are reinforcing. For instance, a market-based measure such as an emissions charge can result in improved environmental performance by: (1) directly increasing the marginal benefits of abatement; and (2) encouraging the introduction of an environmental management system and consequently indirectly reducing the marginal costs of abatement.

However, such reinforcing effects may not always predominate. For instance, the anecdotal evidence referred to above which reports the positive role that EMSs have played in bringing about improved environmental performance is often drawn from firms which decided to introduce such measures endogenously, without the provision of direct incentives for their introduction.[6] In effect, the introduction of a policy incentive can have an effect on the management–performance relationship. Unless the incentives – such as the provision of technical assistance or public recognition – are designed astutely, the relationship is likely to be less strong in the presence of exogenous policy influences. It is, therefore, important to bear this in mind when designing the estimation framework.

On the one hand, the nature of the relationship may be affected by the type of facility which is encouraged to introduce an EMS by the policy incentive. For instance, a public recognition programme may be more valuable to firms for whom signalling of environmental characteristics is particularly important. Whether or not this results in the introduction of an equally efficient EMS warrants further analysis. Conversely, the provision of technical assistance or financial assistance may be particularly valuable to smaller, less-informed facilities. The returns of an EMS in terms of performance may be very different in such cases.

In some cases, the effect may even be negative. This can be illustrated by using the example of one particular policy measure promoting EMS diffusion: announcing a reduction in the frequency of inspections if an EMS is implemented. Fewer inspections potentially lead to countervailing effects on environmental performance:

- A positive effect on the propensity to adopt an EMS: the policy increases the probability that a given firm will introduce an EMS by shifting up the marginal benefits curve. This is the primary goal of the measure.
- A positive effect on environmental performance: assuming that the EMS improves the firm's performance for various reasons (for example, it enables the firm to identify cost-reducing abatement actions), the positive effect on the propensity to adopt an EMS also results in a positive indirect effect on environmental performance.
- A negative effect on the marginal benefit of abatement: the facility may diminish its compliance propensity, and abatement, because marginal abatement benefits are lowered by the fact that the probability of being caught in case of non-compliance is reduced.

It is perfectly possible in theory that the negative effect outweighs the positive effect so that the net effect of the policy could be negative. Other measures which may have such an effect include expedited permitting procedures.[7] Moreover, it is not even necessary for there to be an explicit policy of this kind in place. If firms believe that the presence of an EMS will expedite the permitting process or reduce the frequency of inspections, this will suffice. For instance, it is widely recognized that environmental inspections are not randomly distributed, but are often determined on the basis of 'rules of thumb' and past behaviour (see Harrington 1988). As such, if an EMS is thought to be used by environment agencies to sort facilities with respect to the frequency of inspection rates, this is sufficient to generate this potential effect (see Lyon and Maxwell 1999 for a discussion).

This would, of course, be even truer of other EMS-promoting policies which potentially have an even more evident impact on the marginal benefits of abatement. For instance, measures such as the provision of regulatory relief, either by reducing regulatory stringency, penalty mitigation, or by substituting the presence of an EMS for regulatory standards, are likely to have very pronounced effects on the performance decision. In this case, the policy maker is implicitly attaching a great deal of faith in the exogenous benefits associated with the introduction of an EMS – that is, it will improve performance even if the direct incentives to do so are less important.

The potential drawback of addressing the EMS and performance equations separately is now apparent, since there can be discrepancies between the direct and indirect effects of policy measures. By contrast, if we jointly address the EMS decision and the performance decision, we are able to disentangle the direct (negative) effect of reducing the frequency of inspections on the marginal benefits of abatement from its indirect (positive) effect through the implementation of an EMS. In effect, since the motivation for the introduction of an EMS matters, it is important to estimate the two equations as part of a single system.

Estimation Framework and Principal Hypotheses

It is due to these issues of endogeneity (between the management and performance decisions) and selection (due to the presence of correlated omitted variables) that the assessment of the effects of public policies on both the EMS decision and the environmental performance decision necessitates the use of an appropriate methodology, involving simultaneous estimation techniques. The 'system' to be estimated (and the potential interactions within the system) are depicted in Figure 3.6.

On the one hand, general environmental policies (that is, emission charges, technology standards, and so on) affect the firm's abatement decision, as intended. It is, however, interesting to examine how effective certain instruments are in doing so, particularly with the rise of voluntary measures. On the other hand, the nature of the instrument may also affect the decision to introduce and environmental management system. It has been posited that an EMS may provide greater relative benefits in the presence of 'flexible' policy measures such as market-based instruments and performance standards (see Figure 3.6).

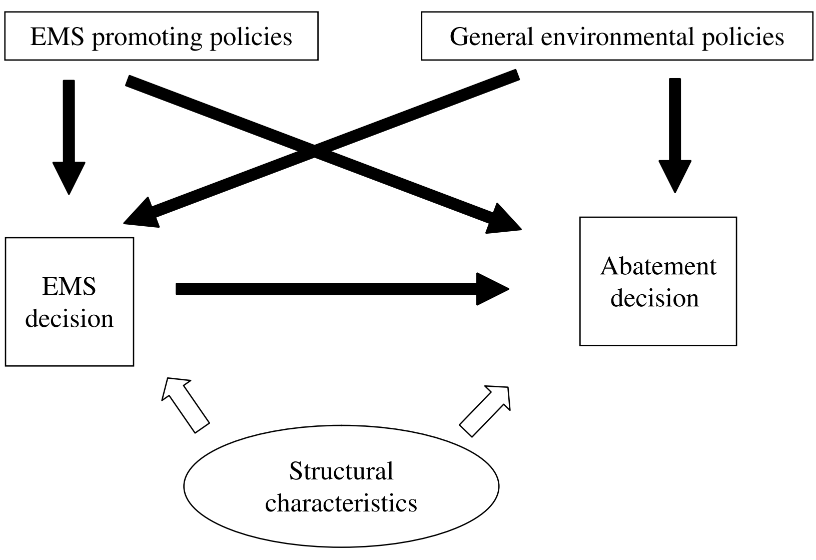

Figure 3.6 The direct and indirect effects of public policy measures

Table 3.2 Principal hypotheses examined

	Environmental management	Environmental performance
EMS-promoting policies	Effects of different measures on probability of introducing EMS (i.e. supply vs. demand)	Indirect effects of such measures on environmental performance (i.e. regulatory relief)
General environmental policies	Indirect effects of different measures on probability of introducing EMS (i.e. flexible vs. prescriptive)	Effects of such measures on environmental performance (i.e. mandatory vs. voluntary)

Similarly, EMS-promoting policies such as the provision of financial assistance or public recognition have a rather obvious effect on the decision to introduce and EMS, whether by reducing costs (financial or technical assistance) or by increasing benefits (public procurement or recognition). However, they can also affect the abatement decision. On the one hand this effect is transmitted through the introduction of the EMS itself, and the implications this has for abatement costs. However, on the other hand, the incentive itself may play a role. This is most obviously the case when regulatory relief is provided, permitting procedures are expedited, or when inspection frequency is reduced.

Our principal policy hypotheses are, therefore, summarized in Table 3.2, with each type of policy impacting upon both the EMS decision and the environmental performance decision. In addition, the more general role played by both perceived policy stringency and inspection frequency on both of these decisions can examined.

V. DATA AND DESCRIPTIVE STATISTICS

The survey used for estimation was undertaken by OECD in the spring of 2003 (see Chapter 1 for a full description of the data. The questionnaire is available at www.oecd.org/env/cpe/firms). As noted, the main themes addressed in the questionnaire concern:

- the management systems and tools in place in the facility (environment related or not) and the institutional location of environmental responsibility organization within the firm (if any);
- the potential environmental impacts of the facility, the measures undertaken to reduce them, and their results;

- the influence of stakeholders and motivations on environmental practices;
- the public environmental policy framework (stringency, relative importance of different instruments, frequency of inspections, and so on);
- and the facility's structural characteristics (size, scope of the market, competition factors and commercial variables).

Some of the principal responses to questions of particular relevance to this report are summarized below.

Environmental Actions and Performance

Respondents were requested to report on whether in the last three years they had:

- significant potential environmental impacts associated with their facility – scale from 1 (no negative impacts) to 3 (very negative impacts);
- undertaken significant concrete actions to reduce environmental impacts – binary response; and,
- reported changes in environmental impacts per unit of output – scale from 1 (significant decrease) to 5 (significant increase).

These questions were posed for a number of different environmental impact areas (solid waste generation, wastewater effluent, air pollution, soil contamination, risk of severe incidents). Parenthetically, we note that there is a reassuringly high degree of correlation between facilities which report having undertaken concrete measures in those areas for which they feel that the potential negative environmental impacts were important. In addition, reported actions and reported improvements in environmental performance are also highly correlated. In the analysis below we work with the performance data.

Over three-quarters of facilities declared having undertaken actions to reduce solid waste generation. At the other extreme, the percentages for soil contamination and global pollutants are lower. However, concerning performance, solid waste generation and wastewater effluent are the two areas in which the most progress had been made. Global air pollutants (and to a lesser extent soil contamination) were the areas with the least improvement (see Tables 3.3 and 3.4).

As discussed in greater detail below, the estimation was undertaken applying the *PERFORMANCE* variable (reported changes in impacts) for only

Table 3.3 'Concrete actions' undertaken in the last three years

	Use of natural resources	Solid waste generation	Waste-water effluent	local or regional air pollution	Global pollution	Aesthetic effects	Soil contamin.	Risk of severe accidents
No	899	699	891	1177	1695	1136	1352	961
Yes	2893	3135	2577	1958	1042	2187	1338	2166
Not applicable	336	300	672	982	1365	799	1426	955

Table 3.4 Changes in environmental impacts in the last three years

	Use of natural resources	Solid waste generation	Waste-water effluent	local or regional air pollution	Global pollution	Aesthetic effects	Soil contamin.	Risk of severe accidents
Significant decrease	270	319	272	220	129	151	150	215
Decrease	1643	1727	1144	1002	649	1083	445	1059
No change	1418	1350	1695	1539	1451	1752	1557	1466
Increase	269	253	162	83	73	67	6	36
Significant increase	19	16	10	4	1	5	3	7
Not applicable	359	327	704	1118	1639	910	1800	1148

three of these areas: solid waste generation, local or regional air pollution, and wastewater effluent. This choice was made on the basis of the results of a Varimax analysis, which indicated that these impacts were found to be representative of three of the four clusters into which the different impacts grouped themselves. In addition, they are the standard environmental media by which much of environmental policy is categorized.

Environmental Management

As noted in Chapter 1, 70.3 per cent of facilities reported having an individual with explicit responsibility for environmental matters. Of these, the largest percentage reported that they were in senior management positions, followed by specialized environmental health and safety departments, and production and operations. None of the other categories reported significant response levels.

The environmental management decision is reflected in the binary response to the question: 'Has your facility actually implemented an environmental management system?' (Question 1.6). Respondents were also requested to indicate the year in which an EMS was first implemented, and whether or not it was certified, and if so under which scheme. The percentage of facilities reporting that they had environmental management systems is 38.8 per cent, but it varies widely across countries, with figures ranging from just under 30 per cent (Germany and Hungary) to almost 57 per cent (United States). Over 1000 facilities reported having some form of certification, whether EMAS or ISO 14001. As expected, smaller facilities are less likely to have environmental management systems in place. For the smallest class (<100 employees) less than 20 per cent of facilities have an EMS, while for the largest class (>500 employees) the figure is over 60 per cent.

Questions were also asked about the presence of specific environmental management tools (for example environmental accounting, reporting, training, and so on), but these have not been applied in the econometric analysis which follows. Nonetheless, it is interesting to note some important differences across countries. Generally speaking, the presence of a written environmental policy is the most prevalent tool. Hungary and Norway report a high prevalence of public environmental reports. Environmental accounting is very rare, except in Germany. In Japan, the benchmarking of environmental performance is relatively more important than elsewhere (see Chapter 1).

The relationship between environmental management and reported environmental performance appears to be quite strong. Table 3.5 provides data on the percentage of facilities that report having experienced a

Table 3.5 Reported decrease in impacts against status of EMS (%)

	Solid waste	Air pollution	Water pollution
NO EMS	45.4	37.2	37.0
EMS in progress	58.9	46.5	52.9
EMS	68.4	47.1	48.6

decrease in environmental impacts in the last three years according to status of implementation of EMS. There is a clear difference, with those having implemented an EMS much more likely to report decreased impacts. Whether this relationship holds in the empirical analysis is discussed in section VI below.

Environmental Policy

Facilities were asked about the perceived importance on their production practices of different policy instruments, such as technology-based standards, performance-based standards, taxes (on input, on emissions), tradable permits, voluntary agreements and so on, on a scale from 1 (not important) to 3 (very important). Not surprisingly, technology-based standards and performance-based standards are said to have the most influence, although it is interesting to note the very low response for technology-based standards in Japan. Subsidies and voluntary agreements appear to play a more important role in Hungary than elsewhere (see Figure 1.3 in Chapter 1).

As noted in Chapter 1, it is important to note that the perception of the influence of the policy measure may be affected by its nature. For instance, the visibility of economic instruments may lead respondents to overstate their relative influence. Moreover, because of their relatively recent application in many countries, respondents may be more aware of their influence on their behaviour than other measures (that is, direct regulations) in which their responses are already 'sunk' in capital costs. In order to address this issue in the estimation which follows, binary variables were created on the basis of whether the instrument was in place (irrespective of reported influence) or not ('not applicable').

The database also provides data on the perceived stringency of policies. This information is useful. In fact, one might have thought that a facility perceiving a high degree of stringency would have given maximum values in its responses concerning the different type of policy measure. However, this variable lets us control for this possibility, and the relative impact of each policy may be measured. In Figure 3.7 the relationship between

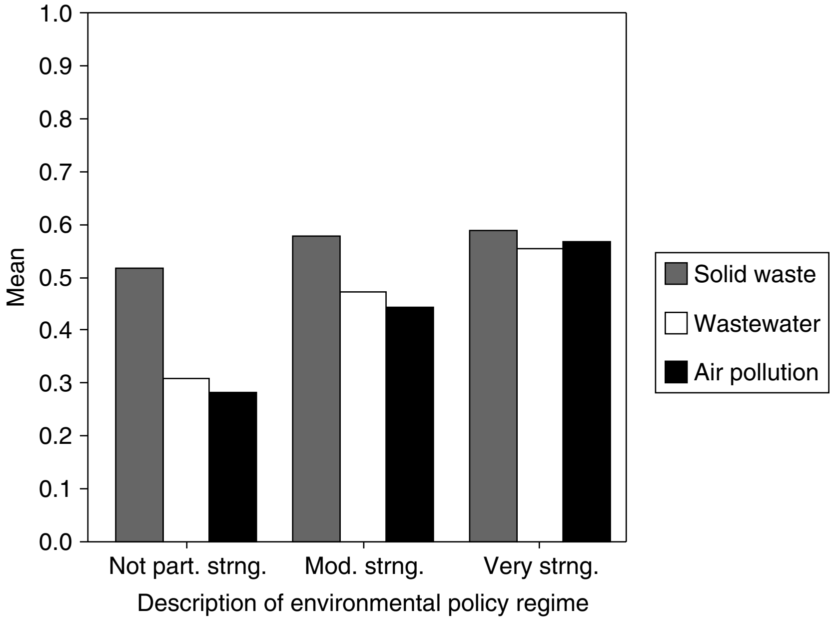

Figure 3.7 Perceived policy stringency and reported environmental performance (% reporting decrease)

perceived policy stringency ('not particularly stringent', 'moderately stringent' and 'very stringent') against reported decreases in three environmental impact areas is given. In all three cases stringency is associated with reported decreases, although in the case of solid waste Chi-square tests do not confirm the significance of the change.

The frequency of inspections in the last three years was reported as well, and the distribution of responses is reported in Chapter 1. The mean response across all countries was just over 3.6 inspections over the three-year period (that is, 1.2 per year), but it is very skewed. Over 1000 facilities (30 per cent) report not having been inspected in the last three years, and almost 7 per cent report having been inspected over ten times. A large number of facilities report never having been inspected in the last three years in Hungary. Facilities in Japan and the United States report the highest average inspection frequency rate.

Table 3.6 gives the relationship between inspection frequency and reported environmental performance in the last three years, with a negative sign on the correlation coefficient indicating that those who report being inspected frequently are more likely to report increased environmental impacts. The correlation coefficients are significant and negative in all but

Table 3.6 Correlation coefficients for inspection frequency and reported changes in environmental impacts

Environmental impact	Statistic	Result
Use of natural resources	Pearson Correlation	−0.042*
	Sig. (2-tailed)	0.015
	N	3320
Solid waste generation	Pearson Correlation	−0.010
	Sig. (2-tailed)	0.547
	N	3363
Wastewater effluent	Pearson Correlation	−0.063**
	Sig. (2-tailed)	0.000
	N	3015
Local or regional air pollution	Pearson Correlation	−0.092**
	Sig. (2-tailed)	0.000
	N	2639
Global pollution	Pearson Correlation	−0.060**
	Sig. (2-tailed)	0.006
	N	2147
Aesthetic effects	Pearson Correlation	−0.069**
	Sig. (2-tailed)	0.000
	N	2816
Soil contamination	Pearson Correlation	−0.122**
	Sig. (2-tailed)	0.000
	N	2009
Risk of severe accidents	Pearson Correlation	−0.070**
	Sig. (2-tailed)	0.000
	N	2568

Notes:
** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

one case (solid waste generation). This indicates that the variable reflects targeting of inspections.

Finally, firms were asked about specific EMS-promoting policies. The questionnaire proposed ten types of policies used to incite facilities to put EMSs in place. They can be summarized in a few broad types: supply policies, affecting the marginal cost of EMS curve (such as providing a technical or financial support); demand-side policies, which primarily affect the benefit curve of EMS (such as procurement preferences or special recognition); and those policies which may affect the performance decision as well, such as a reduction of the frequency of inspections, or reducing the stringency of environmental regulations.

In the United States, a large percentage of facilities feel that regulatory relief is provided (reduced frequency of inspections, lower regulatory standards). In Hungary, a large percentage of facilities feel that incentives are provided in the form of expedited permitting procedures. In France, financial support appears to be common. In general, demand-side measures are less common, except in the United States. Japan does not appear to provide significant incentives of any kind.

VI. ESTIMATION PROCEDURE

Estimation proceeded in stages, with single-equation estimation of the management and performance decisions being the first stage. Subsequent to this, bivariate probit estimation was applied in order to address the issue of simultaneity. And finally, an endogenous switch model was applied in order to take into account the potential for selection bias, and structural differences in the performance equations for those facilities with and without environmental management systems.

Single-Equation Probit

Let us assume that the management and performance decisions can be represented by equations:

$$PERFORMANCE = f(EMS, POLICY, X, \varepsilon_1)$$

where *PERFORMANCE* is the performance level, *EMS* is the variable describing the facility's level of environmental management, *POLICY* is a vector of different policy variables and *X* are variables controlling for various aspects of the facility's structural characteristics (facility size, sector, and so on). ε_1 is a random variable with zero mean, which captures unobserved heterogeneity.

The management equation is then:

$$EMS = g(POLICY', Y, \varepsilon_2)$$

where *POLICY′* is a policy vector, which may have some elements in common with *POLICY*. *Y* is a set of control variables distinct from *X*, and ε_2 a zero mean random variable.

The discussion in the previous parts led us to conclude that, in order to study the links between a firm's environmental performance and presence of EMS, it is necessary to estimate performance and management choice equations simultaneously. In fact, the indirect effects of policies on environmental performance through the introduction of an EMS could not be taken in account if the equations are estimated separately. Moreover, recall that the self-selection issue in the EMS choice has been shown to be equivalent to an unobserved variable (for example, being a laggard or a leader), which could induce a correlation between both residuals ε_1 and ε_2, and which cannot been examined if the estimations are undertaken separately.

Bivariate Probit

One possible econometric solution consists in the use of instrumental variables, and selection models. However, as the interest variable we use here to represent performance and management are binary, specific difficulties arise in comparison with the framework applied for continuous variables.

We present an estimation pattern adapted to the case of binary dependent variables and endogeneity issues. Our equations can be expressed as:

$$PERFORMANCE^* = \alpha\ POLICY + \beta EMS + \gamma\ X + \mu_1$$
$$PERFORMANCE = 1_{(PERFORMANCE^* > 0)}$$
$$EMS^* = \alpha'\ POLICY' + \gamma'\ Y + \varepsilon_2$$

where *PERFORMANCE** and *EMS** are the usual latent variables determining Performance and EMS.

As detailed above, single equations give some indication of the role of different structural and policy factors on the facility's decisions with respect to both management and performance, but cannot provide a satisfying estimation framework. The bivariate probit model allows for the simultaneous estimation of parameters of the performance equation and of the EMS choice equation. This global estimation procedure enables us to test the presumed endogeneity of EMS choice, and the effect of this tool when endogeneity is taken into account. This estimation can be undertaken by maximizing the likelihood of the previous model.

As in the case of instrumental variables estimation, in bivariate probit models we need to exclude one of the variables common to the EMS from the performance equation. We chose for this role the variable concerning financial support to implement an EMS. Theoretically, this variable is not suspected to result in moral hazard issues, and thus can reasonably be expected only to intervene in the second (EMS) equation. Moreover, previous estimations show that this variable had a significant impact on EMS.

The weakness of the bivariate probit approach is that we consider that there is only one common value for each determinant of the actions, and the presence of an EMS is one of these determinants. Stated differently, the impact of a special determinant, especially a policy variable, will not change with the EMS situation: irrespective whether there is an EMS or not in place, the model will predict the same coefficient for a given variable. If our goal is to compare the differences between with/without EMS situation, we will only be able to compare two different constant terms, one corresponding to the no EMS situation (constant term + 0 * EMS coefficient), and the other corresponding to the EMS situation (constant term + 1 * EMS coefficient).

This specification is also restrictive if we want to know more about the changes induced by an EMS in a facility's decision function with respect to performance. In fact, we could imagine that the introduction of an EMS could change the impacts of other determinants, as would be the case if an EMS introduced structural changes within the facility.

Endogenous Switch Models

These shortcomings lead us to the next step: the endogenous switch model. This model is more flexible, allowing the coefficients of the different determinants to be different between the two regimes (with/without EMS). The estimation is done by modelling first the decision to introduce an EMS, followed by the estimation of environmental performance under both regimes. The latter is estimated separately for the sub-sample of facilities which have introduced an EMS (REGIME 1) and those which have not (REGIME 0). The principle is the same as in the switch model equations, but the difference is that the fact of belonging to a particular regime is not assumed to be exogenous, but endogenous.

Moreover, in the second equation, the set of variables can differ from one regime to the other. As such, it is also possible to introduce different explanatory variables for performance according to the regime (1 or 0). For instance, for facilities with EMSs in place, it is possible to assess the role of certification of an EMS. Is there value added (in terms of performance) associated with certification? In addition, the role of temporal lags can be assessed. For instance, the question of whether the benefits of EMSs only accrue after a time can be examined.

The model is estimated under the hypothesis that two possible levels of performance exist for every firm, one if there is an EMS ($PERFORMANCE^1$), and another if not ($PERFORMANCE^0$). Of course, only one of the two performance outcomes is observed.

$$PERFORMANCE = PERFORMANCE^1 \quad \text{if, } EMS = 1$$
$$PERFORMANCE = PERFORMANCE^0 \quad \text{if, } EMS = 0$$

As we are looking for the determinants of performance, we introduce the effect of the explanatory variables on performance and EMS as:

$$PERFORMANCE^1 = 1(\alpha_1 \; POLICY_1 + \beta_1 \; X_1 + \varepsilon_1 > 0)$$
$$PERFORMANCE^0 = 1(\alpha_0 \; POLICY_0 + \beta_0 \; X_0 + \varepsilon_0 > 0)$$
$$EMS = 1(\alpha' \; POLICY' + \beta' \; Y + \mu > 0)$$

It is important to note that the policy variable vector can be very different for the two regimes, particularly if 'directed' policies are applied to promote EMSs. Moreover, the other variables may differ since some variables will exhibit no variability within the EMS = 0 sub-sample (that is, year of introduction of EMS or whether it is certified).

VII. RESULTS

The results section is divided into three subsections, in line with the theoretical discussion above. In the first subsection the results from single-equation probit models are reviewed, using responses to questions 2.3[8] and 2.6[9] with respect to air and water pollution as the dependent variables. In the second subsection, results of bivariate probit models are presented in which equations with the same dependent variables alongside an equation estimating the probability of having implemented an environmental management system. In the third subsection, the results of selection models are presented in which the environmental management variable is as the modelled 'treatment' variable.

Single-Equation Probit Results

The results (Table 3.7; full results are available at www.oecd.org/env/cpe/firms) indicate that perceived policy stringency and inspection frequency have positive and significant effects on both the likelihood of reporting a reduction in environmental impacts per unit of output and the likelihood of having undertaken actions to reduce such impacts. In five of six equations the effect of policy stringency is positive and statistically significant (at the 10 per cent level). This was most important for the estimation of concrete actions related to air pollution, for which the marginal effect was 0.177. For most of the others the marginal effect is in the region of 0.1.

Inspection frequency plays a more ambiguous role, being significant in five equations, but the marginal effect never exceeds 0.1. In one case it has a negative sign (solid waste impacts). The negative result may reflect the dominant effect of targeting on the part of enforcement agencies, with

Table 3.7 Statistically significant (10%) variables of univariate probit models

Change in impact			Concrete action		
Air pollution	Water pollution	Solid waste	Air pollution	Water pollution	Solid waste
Policy framework					
Pol. strng. (+)	Pol. strng. (+)	Insp. freq. (−)	Pol. strng. (+)	Pol. strng. (+)	Pol. strng. (+)
Insp. freq. (+)			Insp. freq. (+)	Insp. freq. (+)	Insp. freq. (+)
Instrument choice					
	Poll. tax (+)		Perf. std. (+)	Perf. std. (+)	
	Input tax (−)			Tech. std. (−)	
Economic variables					
Fac. empl. (+)		Fac. empl. (+)	Fac. empl. (+)	Fac. empl. (+)	Fac. empl. (+)
Price comp. (−)		Mrkt conc. (+)	Price comp. (−)		Price comp (+)
		Final good (+)	Img. comp. (+)		Profitability (+)
		Sales chng. (−)			
		Profitability (+)			
		Qual. comp (+)			
Management variables					
EMS (+)	EMS (+)	EMS (+)	EMS (+)	EMS (+)	EMS (+)
	Env. resp. (+)	Env. resp. (+)	Env. resp. (+)	Env. resp. (+)	Env. resp. (+)

worse performers being inspected more frequently in the case of solid waste.[10]

Examining whether or not the use of particular environmental policy instruments have an influence (above and beyond policy stringency), in general little apparent difference is found – that is, the precise nature of the mix of instruments applied does not play an important role in terms of environmental effectiveness when policy stringency is controlled. Nonetheless, performance standards have a significant and positive role in two cases, and pollution taxes in one case. Conversely, the presence of input taxes (water pollution impact) and technical standards (water pollution action) has a negative influence in one case each. This result may arise from the fact that the introduction of a particular policy measure reduces the probability of another measure being in place. And if this measure tends to be relatively lax (even if not perceived as such), then it may have a negative impact.

Environmental management variables have a consistently significant impact, with the presence of an environmental management system having a positive and significant impact in all six cases. In the case of reported performance with respect to solid waste, the marginal effect equals 0.162. In addition, the presence of an individual explicitly responsible for environmental matters has a significant and positive influence in five of six equations. This is most important in the area of water pollution, in which the marginal effects exceed 0.1. Additional unreported estimates indicated that the precise location of this individual did not have a significant influence.

Of the economic and structural variables, facility size has a positive relationship with both the environmental performance and action variables (five out of six equations). Facilities which compete on the basis of price are worse performers with respect to air pollution, but in the case of solid waste actions the effect is negative. Competition on the basis of firm image has a positive role in one case (air pollution actions). Facility profitability has a positive and significant influence in two cases, while change in sales has a negative influence in one case.

Bivariate Probit Results

A summary of the principal results from the bivariate probit models (using the presence of an environmental management system as the dependent variable in the additional equation) is presented in Table 3.9. First, however, Table 3.8 summarizes the tests of endogeneity. At the 10 per cent level, the rho-statistic (testing for correlation between the residuals) indicates endogeneity between determinants of environmental performance and actions and the presence of an environmental management system in the system of equations for air pollution impact, water pollution impact, solid waste impact, and solid waste action.

The coefficient estimates for the performance and actions largely confirm the results above. Significantly, the variable reflecting the presence of an environmental management system is no longer significant in two of the equations estimated – air pollution action and water pollution action. This result is to be expected if the two variables are simultaneously determined and estimated as a system. However, it must be noted that the EMS variable remains significant in four out of six equations (air pollution impact,

Table 3.8 Results of endogeneity rho-tests in bivariate probit models

Change in impact			Concrete action		
Air pollution	Water pollution	Solid waste	Air pollution	Water pollution	Solid waste
0.0011	0.0290	0.0018	0.2966	0.7349	0.0053

Table 3.9 Statistically significant (10%) variables of bivariate probit models (performance equations)

Change in impact			Concrete action		
Air pollution	Water pollution	Solid Waste	Air pollution	Water pollution	Solid waste
Policy framework					
Pol. strng. (+)	Pol. strng. (+)	Insp. freq. (−)	Pol. strng. (+)	Pol. strng. (+)	Pol. strng. (+)
			Insp. freq. (+)	Insp. freq. (+)	
Instrument choice					
	Poll. tax (+)		Perf. std. (+)	Perf. std. (+)	
	Input tax (−)				
Economic variables					
Price comp. (−)	Byrs comp. (−)	Qual comp (+)	Price comp. (−)		Final cust. (+)
	Firm quote (−)	Final cust. (+)	Fac. empl. (+)		Profitability (+)
		Sales chng. (−)			
		Mrkt conc. (+)			
Management variables					
EMS (+)	EMS (+)	EMS (+)	Env. resp. (+)	Env. resp. (+)	EMS (+)
	Env. resp. (+)	Env. resp. (+)			Env. Resp. (+)

water pollution impact, solid waste impact and solid waste performance), even when the two dependent variables are endogenous. In terms of total marginal effects – that is, including the direct and indirect impacts on performance – the marginal effect of the presence of an environmental management system on the likelihood of reporting having improved its performance is 0.63, and never less than 0.1 for the other areas.

Policy stringency continues to play an important role. However, the highest marginal effect is 0.186 (air pollution performance). Inspection frequency has decreased in importance and the total marginal effect is often very small (less than 0.01). Differences in the mix of environmental policy variables applied play largely the same role in the environmental impact and action equations in the bivariate models as in the univariate models.

However, the nature of the environmental policy regime does appear to influence the decision to implement an environmental management system. Performance standards and voluntary approaches have a positive influence in many cases. For instance, in the area of air pollution actions, the total marginal effect is 0.13. The result for voluntary approaches may be explained in part by the fact that some respondents view an EMS in and of itself as a voluntary agreement. Interestingly, input taxes play a negative role on the EMS decision in four out of six equations.

Importantly, of the 'targeted' policy measures to encourage the introduction of environmental management systems and tools, the only two which have the most important influence appear to be the provision of financial support and, very significantly, reduced inspection frequency. In all six equations, perceived reduction in inspection frequency plays a significant and positive role on the decision to introduce an EMS. None of the other potential incentives appear to have a statistically significant influence. This highlights the importance of examining the effect that this may have on performance in the selection equations.

Endogenous Selection Model Results

The principal results of the selection models are presented in Table 3.10, reporting results according to the environmental medium. Our primary concerns in this case are: to distinguish between the effects of different variables in the $EMS = 1$ and $EMS = 0$ cases; the importance of EMS certification and age in the $EMS = 1$ sample; and the role of targeted environmental management incentives on performance. In one case (solid waste actions for facilities with an EMS), the model does not converge. Overall policy stringency remains significant, with the solid waste models being a significant exception. Inspection frequency also plays a role, but only with respect to actions and not reported changes in impacts. Instrument choice is even less important than in the previous models, although it does appear to matter more for facilities which do not have an EMS. The signs on the statistically significant policy instrument variables are consistent with previous results.

Table 3.10 Statistically significant (10%) variables of air pollution selection models

Change in impact		Concrete action undertaken	
EMS = 0	EMS = 1	EMS = 0	EMS = 1
Air pollution			
Policy stringency (+)	Policy stringency (+)	Policy stringency (+)	Policy stringency (+)
Mult. facility (+)	Fac. empl. (−)	Insp. frequency (+)	Insp. frequency (+)
Final good (−)	Change in sales (+)	Perf. standard (+)	Intl market (−)
Price comp. (−)		Input tax (−)	Image comp (+)
		Intl mrkt (+)	Procurement pref's (−)
		Env. resp (+)	
Water pollution			
Policy stringency (+)	Intl. mrkt (−)	Policy stringency (+)	Policy stringency (+)
Input tax (−)	Certification (+)	Insp. frequency (+)	Insp. frequency (+)
Firm quote (−)		Tech. standard (+)	Perf. standard (+)
Env. resp (+)		Price comp. (−)	
		Byrs comp (−)	
		Env. resp. (+)	
Solid waste			
Final good (+)	Insp. freq. (−)	Vol. agr. (+)	
Change in sales (−)	Vol. agr. (+)	Firm quote (−)	
	EMS age (+)	Facility empl. (−)	
	Certification (+)	Env. resp. (+)	

With respect to environmental management, certification plays a role for water pollution performance and solid waste performance. The length of time which an EMS has been in place influences solid waste performance as well. The hypotheses concerning potential adverse effects of certain targeted EMS-promoting policies are not borne out strongly. Preferences for public procurement for facilities with an EMS has a negative influence on actions in the area of air pollution, indicating that the provision of such incentives may encourage facilities to introduce EMSs as a signal to public authorities, rather than as a means to improve their environmental performance. And finally, for facilities that do not have an EMS it appears that designating somebody as explicitly responsible for environmental matters plays a substitute role.

Table 3.11 Average treatment effects

	Effect on latent variable	p-value	Effect on probablity	p-value
Solid waste impact	1.08	0.005	0.39	0.00
Air pollution action	0.27	0.74	0.10	0.72

In order to allow for the calculation of the average treatment effects of EMSs, the same models were also estimated using SAS (see Table 3.11). However, only those models for solid waste impacts and air pollution actions converged. The results for these models are very similar to those reported above, and the average treatment effects indicate that EMSs have a significant influence in the case of solid waste performance, but not air pollution action.

Tests of Robustness

In addition to undertaking estimation on the full sample, the robustness of the results were examined by applying the same models to five sub-samples: small and medium-sized enterprises (less than 250 employees); single-facility firms; the basic and fabricated metals sectors; the machinery, electrical and instruments sector; and the Japanese sub-sample. The inclusion of estimates on the latter was motivated by the size of the sample and apparent differences between the Japanese sample in terms of sectoral distribution and facility size relative to the samples for the other countries. In all cases the univariate models and bivariate probit models were estimated. The summary results are presented in Appendix 3A.

The results for the estimation undertaken on the SMEs are very similar to those for the full sample. One notable difference is the even more significant role played by environmental management systems and the designation of someone as being responsibile for environmental matters. Taking all 12 models together these variables are positive and significant in 23 of 24 cases. In addition, the public policy framework is marginally more important for SMEs. In particular, there are more policy variables which are statistically significant.

Conversely, in the case of single-facility firms the fit is generally much less satisfactory than for the full sample. This is particularly true of the models related to solid waste and (to a lesser extent) water pollution. For instance, in the case of reported change in impacts related to solid waste generation there are very few statistically significant variables for single-facility firms.

For the basic and fabricated metals sectors (ISIC 27–28), the role of EMSs is relatively less important than for the full sample. Indeed, in two of the bivariate models their presence has a negative influence. In addition, the policy framework is less important in the water pollution models than for the full sample. And finally, economic factors appear to play a more important role for the two air pollution models than in the full sample.

In the case of the machinery, electrical and instruments sector (ISIC 29–33), the public environmental policy framework is less important for water pollution. More generally, the fit for the solid waste models is less satisfactory than for the full sample. The role of EMSs and the designation of somebody as responsible for environmental matters appear to be marginally less important.

And finally, estimation on the Japanese sub-sample reveals some important differences. Most significantly, the fit of the models for reported change in air pollution and water pollution impacts is much less satisfactory than for the full sample. The role of public policy appears to be limited. However, this is not true with respect to reported actions in these two areas.

VIII. CONCLUSION

This report has examined the links between the public policy framework and environmental performance, as reflected in self-reported changes in environmental impacts and concrete actions undertaken. Based upon a survey of over 4000 manufacturing facilities in seven OECD countries, the role of different elements of policy framework (policy stringency, inspection frequency, instrument choice, and incentives for improved management) have been examined.

The results of the single-equation estimation models have been presented. However, the possible endogeneity of the decision to implement an EMS has led us to rely on simultaneous equations techniques of estimation. More specifically, we use a bivariate probit model whose key assumption is to consider that an EMS only has a fixed effect on the performance. Second, we use an endogenous switch model which is more flexible in that it estimates the performance equation on the two sub-samples: EMS and non-EMS facilities. It must, however, be emphasized that the use of a single cross-section does place limitations on the analysis.

Bearing this limitation in mind, it is interesting that perceived policy stringency consistently appears to be significant. Reported frequency of inspections is also a significant determinant of changes in environmental impacts and actions undertaken. However, the role of using environmental performance to target facilities for inspections – which would have a countervailing influence on the sign – needs to be examined in more detail in further work.

Instrument choice seems to matter less – that is, once the effect of policy stringency is accounted for, the precise mix of instruments applied is not particularly important. When statistically significant, performance standards and pollution taxes have a positive influence. Conversely, reliance on input taxes has a negative influence and there is no obvious reason why this may be the case – except perhaps that they are often set too low for political reasons, and once in place incentives to introduce other measures as complements are less acute (or else they would be statistically insignificant). In addition, technology standards occasionally have a significant and negative influence as well.

In addition, the presence of an EMS is consistently shown to have a significant positive impact on performance in the univariate probit models. However, the role of an EMS is somewhat less significant when the interdependence of the two decisions is modelled appropriately. This is as expected. Nonetheless, the role of EMSs remains significant in four of the six bivariate probit equations, and calculation of the average treatment effects in the selection models indicate that they have an appreciable influence of performance.

The selection models also indicate that for those facilities with EMSs in place, certification of the EMS and the length of time which it has been in place appear to be somewhat significant influences, with results consistent with a priori expectations. However, they are statistically significant in very few of the models. More experience with EMSs may be required to assess the effects of age and certification. Moreover, the fit of the selection models is such that these results need to be treated with caution.

Of the 'targeted' incentives to introduce an EMS, the two which have the most important influence appear to be the provision of financial support and reduced inspection frequency. None of the other incentives are statistically significant in any of the models estimated. Indeed the role of perceived inspection frequency on the decision to introduce an EMS is perhaps the most robust result obtained overall.

The concern that some targeted incentives may provide 'perverse' incentives on performance is provided only very limited support. For instance, in two of the selection models estimated it appears that the perception that regulatory stringency will be relaxed in exchange for the implementation of an environmental management system results in worse environmental performance. This highlights the importance of designing such incentives with the potential for strategic behaviour on the part of facilities in mind.

Of the general policy variables, voluntary agreements and performance standards often have a positive influence on the decision to introduce an

EMS. The former result may be explained in part by the perception amongst some respondents that an EMS in and of itself is a voluntary agreement. However, removal of this variable did not have an appreciable effect on the results. Input taxes (and sometimes technology standards) often have a negative influence on the decision to introduce an EMS. There is no evident reason to explain the latter finding.

Overall, the results reflect the need to model decisions related to environmental actions and impacts in a theoretically consistent matter. Environmental management decisions are clearly endogenous with respect to environmental actions and impacts. Accounting for this endogeneity has an appreciable effect on the results. Moreover, the use of selection models allows for the testing of policy hypotheses which cannot be undertaken with simpler models. However, further work is required to ensure the robustness of the latter, particularly with respect to the selection models.

NOTES

1. This assumes that the opportunity cost of internal funds is less than market capital costs.
2. Although the latter effect is ambiguous since this may allow for investment in costly investments in environmental improvements.
3. Levy (1995), Dasgupta et al. (2000), Lefebvre et al. (1995), Konar and Cohen (1997), Aden et al. (1999), Henriques and Sadorsky (1996), Hemmelskamp (1999), Arora and Cason (1996), DeCanio and Watkins (1998), Gray and Deily (1996), Nelson et al. (1993), Wheeler and Martin (1992), Blackman and Boyd (1995), Hartman et al. (1993), Pargal and Wheeler (1995), DeCanio (1998), Sharma (2000), Dasgupta et al. (2000), Earnhart and Lizal (2002), Anton et al. (2004) and Khanna and Anton (2002).
4. For examples of such policies actually in place see Coglianese and Nash (2001b) and Speir (2001).
5. This is analogous to Lucas's (1976) classic example of the determinants of investment, in which it is shown that the apparent effects of a particular policy intervention (that is, taxation) based upon the *ex ante* relationship between the two variables (investment demand and tax rates) can not be assumed to hold *ex post*.
6. Speir (2001) refers to an unpublished study by Pilsbury Madison and Sutro which identifies benefits in terms of reductions in compliance costs, compliance levels and administrative costs amongst 33 firms which have introduced EMSs. See also the study by Enroth and Zackrisson (2000) which finds similar results for a Swedish sample.
7. Examples of such programmes can be found in Austria, the United Kingdom and the United States (see Rondinelli 2001; Speir 2001).
8. 'Has your facility undertaken concrete actions to reduce environmental impacts associated with the following . . .?'
9. Has your facility experienced a change in the environmental impacts per unit of output of its products or production processes?'
10. See Johnstone and Scapecchi (2004) for a discussion of these issues.

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APPENDIX 3A ROBUSTNESS (STATISTICALLY SIGNIFICANT VARIABLES – 10 PER CENT)

Table 3A.1 Univariate probit models for SMEs

Change in impact			Concrete action		
Air pollution	Water pollution	Solid waste	Air pollution	Water pollution	Solid waste
Policy framework					
Pol. strng. (+)	Pol. strng. (+)	Insp. freq. (−)	Pol. strng. (+)	Pol. strng. (+)	Pol. strng. (+)
Insp. freq. (+)			Insp. freq. (+)	Insp. freq. (+)	Insp. freq. (+)
Instrument choice					
	Poll. tax (+)		Poll. tax (+)	Perf. std. (+)	Perf. std. (+)
	Inpt. tax (−)		Inpt. tax (−)	Tech. std. (−)	
Economic variables					
Multifac. (+)		Prim. csts. (+)	Img. comp. (+)	Multifac. (+)	Price comp. (+)
Price comp. (−)		Mrkt. conc. (+)			Profitability (+)
		Qual. comp. (+)			
		Sales (−)			
		Profitability (+)			
Management Variables					
EMS (+)	EMS (+)	EMS (+)	EMS (+)	EMS (+)	EMS (+)
Env. resp. (+)	Env. resp. (+)		Env. resp (+)	Env. resp. (+)	Env. resp. (+)

Table 3A.2 Bivariate probit models for SMEs

Change in impact			Concrete action		
Air pollution	Water pollution	Solid waste	Air pollution	Water pollution	Solid waste
Policy framework					
Pol. strng. (+)	Pol. strng (+)	Insp. freq. (−)	Pol. strng. (+) Insp. freq. (+)	Pol. strng. (+) Insp. freq. (+)	Pol. stng (+)
Instrument choice					
	Poll. tax (+) Inpt. tax (−)		Perf. std. (+) Inpt. tax (−)	Perf. std. (+) Tech. std. (−)	
Economic variables					
Price comp. (−)	Byrs. comp. (−)	Prim. csts. (+) Mrkt. conc (+) Sales (−)		Price comp (−)	Profitability (+)
Management variables					
EMS (+) Env. resp. (+)	EMS (+) Env. resp. (+)	EMS (+) Env. resp. (+)	EMS (+) Env. resp. (+)	EMS (+) Env. resp. (+)	EMS (+) Env. resp. (+)

Table 3A.3 Univariate probit models for single-facility firms

Change in impact			Concrete action		
Air pollution	Water pollution	Solid waste	Air pollution	Water pollution	Solid waste
Policy framework					
Pol. strng. (+)	Pol. strng. (+)		Pol. strng. (+)	Pol. strng. (+)	Pol. strng. (+)
			Insp. freq. (+)	Insp. freq. (+)	Insp. freq. (+)
Instrument choice					
Vol. agr. (+)			Perf. std (+)	Perf. std. (+)	
Economic variables					
Multifac. (+)	Prim. csts. (+)	Prim. csts. (+)	Fac. empl. (+)	Fac. empl. (+)	Mrkt. conc. (+)
Price comp. (−)	Fac. empl. (+)	Fac. empl. (+)			Price comp. (+)
		Img. comp. (−)			Profitability (+)
Management variables					
EMS (+)	Env. resp. (+)	EMS (+)	Env. resp. (+)	EMS (+)	EMS (+)
Env. resp. (+)		Env. resp. (+)		Env. resp. (+)	Env. resp. (+)

Table 3A.4 Bivariate probit models for single-facility firms

Change in impact			Concrete action		
Air pollution	Water pollution	Solid waste	Air pollution	Water pollution	Solid waste
Policy framework					
Pol. strng. (+)			Pol. strng. (+) Insp. freq. (+)	Pol. strng. (+) Insp. freq. (+)	
Instrument choice					
			Perf. std. (+)	Perf. std. (+)	
Economic variables					
	Prim. csts. (+)	Mrkt. conc (+) Sales (−)	Fac. empl. (+)	Fac. empl. (+)	Fac. empl. (−) Mrkt. conc. (+)
Management variables					
EMS (+) Env. resp. (+)	EMS (+) Env. resp. (+)	EMS (+) Env. resp. (+)	Env. resp. (+)	Env. resp. (+)	EMS (+) Env. resp. (+)

Table 3A.5 Univariate probit models for the basic and fabricated metals sector

Change in impact			Concrete action		
Air pollution	Water pollution	Solid waste	Air pollution	Water pollution	Solid waste
Policy framework					
Pol. strng. (+) Insp. freq. (+)		Insp. freq. (−)	Pol. strng. (+) Insp. freq. (+)	Pol. strng. (+) Insp. freq. (+)	
Instrument choice					
		Vol. apr. (+)	Perf. std. (+) Tech. std (+)	Perf. std. (+)	Tech. std (−) Poll. tax (+) Input tax (−)
Economic variables					
Multifac (+)	Prim. csts (+) Fac. empl (−) Mrkt. conc (+) Byrs. comp. (−)	Prim. csts (+) Img. comp (−)	Fac. empl. (+) Byrs. comp. (−) Img. comp. (+)	Fac. empl. (+) Byrs. comp. (−) Profitability (+)	Frm. quote (+) Prim. csts. (+) Fac. empl. (+) Comp. price (+) Profitability (+)
Management variables					
	Env. resp. (+)	EMS (+) Env. resp. (+)		Env. resp (+) Env. resp. (+)	EMS (+) Env. resp. (+)

Table 3A.6 Bivariate probit models for the basic and fabricated metals sector

Change in impact			Concrete action		
Air pollution	Water pollution	Solid waste	Air pollution	Water pollution	Solid waste
Policy framework					
Pol. strng. (+)			Pol. strng. (+)	Pol. strng. (+)	
Insp. freq. (+)			Insp. freq. (+)	Insp. freq. (+)	
Instrument choice					
		Vol. agr. (+)	Perf. std. (+)	Perf. std. (+)	
Economic variables					
Firm. intl. (+)	Prim. csts. (+)	Firm. intl. (+)	Firm. intl. (+)		Firm. intl. (−)
Fac. empl. (+)	Fac. empl. (−)	Price comp (+)	Fac. empl. (+)		Prim. csts. (+)
Mrkt. scope (+)	Mrkt. scop (−)	Profitability (+)	Img. comp (+)		
Mrkt. conc. (+)		Mrkt. conc. (+)	Byrs. comp (−)		
Management variables					
EMS (−)	EMS (+)		EMS (−)	Env. resp. (+)	EMS (+)
	Env. resp. (+)				Env. resp. (+)

Tabke 3A.7 Univariate probit models for machinery, electrical equipment and instruments sector (ISIC 29–33)

Change in impact			Concrete action		
Air pollution	Water pollution	Solid waste	Air pollution	Water pollution	Solid waste
Policy framework					
Pol. strng. (+) Insp. freq. (+)	Insp. freq. (+)		Pol. strng. (+) Insp. freq. (+)	Pol. strng. (+) Insp. freq. (+)	Pol. strng (+)
Instrument choice					
Poll. tax (+)			Perf. std. (+)	Perf. std. (+) Vol. agr. (−)	Tech. std (−)
Economic variables					
	Fac. empl. (+) Profitability (+)	Multifac (−) Prim. csts (+) Fac. empl. (+) Mrkt. conc. (+) Sales (−)	Firm. intl. (−) Byrs. comp. (+)	Fac. empl. (+)	Fac. empl. (+) Mrkt. scop (+) Byrs. comp (+)
Management variables					
EMS (+)	Env. resp. (+)	EMS (+) Env. resp. (+)	EMS (+) Env. resp. (+)	EMS (+) Env. resp. (+)	EMS (+) Env. resp. (+)

Table 3A.8 Bivariate probit models for machinery, electrical equipment and instruments sector (ISIC 29–33)

Change in impact			Concrete action		
Air pollution	Water pollution	Solid waste	Air pollution	Water pollution	Solid waste
Policy framework					
Insp. freq. (+)	Insp. freq. (+)		Pol. strng. (+)	Pol. strng. (+)	
			Insp. freq. (+)	Insp. freq. (+)	
Instrument choice					
			Perf. std. (+)		Tech. std. (−)
Economic variables					
		Multifac. (−)		Firm. quote (+)	Byrs. comp (+)
		Mrkt. conc. (+)		Fac. empl. (+)	
		Sales (−)			
Management variables					
	Env. resp. (+)	EMS (+)		EMS (+)	Env. resp. (+)
		Env. resp. (+)			

Table 3A.9 Univariate probit models for Japan

Change in impact			Concrete action		
Air pollution	Water pollution	Solid waste	Air pollution	Water pollution	Solid waste
Policy framework					
			Pol. strng. (+) Insp. freq. (+)	Pol. strng. (+) Insp. freq. (+)	Pol. strng (+)
Instrument choice					
		Poll. tax (−)	Perf. std. (+)	Perf. std. (+) Tech. std. (−)	Perf. std. (+) Tech. std. (−)
Economic variables					
Firm. intl. (+) Fac. empl. (+)		Prim. csts. (+) Fac. empl. (+) Sales (+)	Fac. empl. (+) Img. comp (+) Profitability (+)	Fac. empl. (+) Mrkt. conc. (−)	Fac. empl. (+) Profitability (+)
Management variables					
EMS (+)	Env. resp. (+)	EMS (+) Env. resp. (+)		EMS (+) Env. resp. (+)	EMS (+) Env. resp. (+)

Table 3A.10 Bivariate probit models for Japan

Change in impact			Concrete action		
Air pollution	Water pollution	Solid waste	Air pollution	Water pollution	Solid waste
Policy Framework					
			Pol. strng. (+)	Pol. strng. (+)	Pol. strng. (+)
			Insp. freq. (+)	Insp. freq. (+)	
Instrument choice					
		Poll. tax (−)	Perf. std. (+)	Perf. std. (+)	Tech. std. (−)
Economic variables					
Firm. intl. (+)		Fac. empl. (+)	Fac. empl. (+)	Fac. empl. (+)	Profitability (+)
		Qual. comp. (+)	Profitability (+)	Mrkt. conc. (−)	
		Sales (+)			
Management variables					
EMS (+)	EMS (+)	Env. resp. (+)		Env. resp. (+)	Env. resp. (+)
	Env. resp. (+)				

4. An empirical study of environmental R&D: what encourages facilities to be environmentally innovative?

Toshi H. Arimura, Akira Hibiki and Nick Johnstone

I. INTRODUCTION

Technological innovation is indispensable to dealing with environmental problems, particularly for long-run environmental problems such as global warming. Empirical assessment of the role of environment policy on technological innovation remains limited. Indeed, numerous economic models incorporating environmental issues take technological innovation as exogenous, partly because technological innovation with respect to environmental matters has not been analysed in sufficient depth. From the policy perspective, the characterization of technological innovation as exogenous is not credible or satisfactory. Governments need to assess how they can promote technological innovation in an environmentally-friendly manner.

The Porter Hypothesis (Porter and van der Linde 1995) provides one view on the relationship between environmental policy and technological innovation. It asserts that well-designed environmental regulations can stimulate environment-related technological innovation, which can in turn lead to increased competitiveness in the marketplace. However, the assessment (and indeed interpretation) of the hypothesis is not straightforward. In an attempt to disentangle the different claims Jaffe and Palmer (1997) identified three distinct variants of the Porter Hypothesis.

In their framework, the 'weak' version of the hypothesis is that environmental regulation will stimulate 'certain kinds of innovation'. Why should the stringency of environmental policies induce innovation? Explicitly or implicitly environmental policies result in either a change in the cost of different factor inputs or a change in the relative prices of different goods and services. Thus, environmental regulation affects relative prices or places constraints on firms' production possibilities, and thus induces innovation activities that would not be sought in the absence of the regulation.

Thus, in this version of the hypothesis, the strength of environmental policy is critical in stimulating environmental innovation activities, although there is no claim that the direction or rate of this increased innovation is socially beneficial. Any regulation, however misguided in social welfare terms, could result in significant technological innovation as firms seek to save on those resources for which the regulatory constraint is binding or for which the price has increased. In its simplest form this conclusion is almost banal, but it is still interesting to examine whether or not there is empirical support for the proposition (see Jaffe et al. 2003 for a review of the empirical literature).

As such, and following from the literature on induced innovation, there are likely to be increased returns on the identification of production processes and product design which are 'environment-saving' (see, for example, Ahmad 1966). Firms are more likely to search for such opportunities by investing in environment-related research and development.

The 'narrow' version of the hypothesis asserts that for a given level of policy stringency flexible environmental regulations give firms more incentives to innovate than prescriptive regulations such as technology-based standards. If firms' incentives for environmental technological innovations differ according to the type of environmental policy instruments, then environmental policies should be evaluated from the viewpoint of their long-term effect on innovation, as well as their short-term effects in terms of static efficiency – that is, equalization of the marginal abatement cost among polluters. In this version of the hypothesis, the choice of policy instruments (and not policy stringency *per se*) is the important factor to stimulate environmental technological innovation.

'Flexible' policy instruments (such as performance standards and economic instruments) should give greater incentives for investment in innovation than more prescriptive instruments since they increase the 'space' across which feasible abatement opportunities can be identified. Thus, investment in research and development can be considered as a search cost, and the returns on search are likely to be greater, the greater is the space across which innovations identified can be applied. Since flexible instruments (by definition) increase this space, incentives to invest in research and development will be greater. Conversely, there is little point in investing in research and development if the regulator constrains feasible investment opportunities – a potential shortcoming of prescriptive technology-based regulations.

Finally, the last interpretation of the hypothesis is based on the idea that firms may not pursue all profitable opportunities for the development of new products or production processes, and that environmental regulations can encourage them to do so. This is classified as the 'strong' version of the Porter Hypothesis, and is the one which has elicited the most controversy. According to Porter (1991), when a new environmental regulation is introduced, it can induce firms to 'broaden their thinking and to find new products or processes'. If the collection and assessment of information on resource use and environmental impacts (and their financial implications) is imperfect, environmental issues will not be optimally addressed in the firm's decision making. Thus, firms may miss some profitable opportunities for innovation. Regulation, by providing information, can result in the realization of commercial opportunities.

Thus far, little empirical work has been undertaken to determine why and whether this is the case. However, some theoretical work has cast light on the important role played by organizational structures and management practices on the potential for cost-effective environment-related investments and innovations to be neglected (see Gabel and Sinclair-Desgagne 1993, 1999). As managers seek to align incentives within the facility under conditions of imperfect information and control, there will be cases in which profitable opportunities are lost. Environmental management is expected to assist the firm in making informed decisions with respect to environmental matters, which may also prove to be in their commercial interest. As we will show in the literature review section, some studies highlight the importance of organizational factors in firms' decisions with respect to energy efficiency or environmental matters.

However, the controversy may be more apparent than real. If management systems and practices are endogenous, then apparent lost opportunities may just reflect the lag between the point at which policy (and other) conditions change and the point at which firms introduce managerial practices which reflect this change. With environmental policies in many countries undergoing significant reform, the potential importance of such lags may be reflected in the fact that a large number of facilities have very recently implemented different environmental management practices such as environmental training programmes, environmental audits, environmental accounting and environmental reporting. Given the financial implications of investments in environmental research and development, amongst the different environmental management tools, the specific role of environmental accounting is worthy of assessment. More specifically, if research and development is a search cost, then the information base upon which decisions are taken to incur such costs are crucial, and advanced accounting systems can be a key determinant of this base.

Specifically, an environmental accounting system allows for the quantitative evaluation of the environmental implications of the practices of the firm, and its purpose is to help support management make more efficient decisions concerning the impact of the firm's production practices on the environment (see Boyd 1998a, 1998b for discussions). The environmental effects of firm's investments are measured in monetary terms or physical terms, and are entered on the balance sheet. Hence, firms can take external environmental factors into account in their decision making. More significantly for this study, environmental accounting systems quantify the environment-related financial costs and benefits of different investments, providing a company with information for internal decision making in much the same way as in managerial accounting (Kokubu 2000).

Thus, if a firm adopts such an environmental accounting system, it will be more prone to examine various long-term aspects of its production processes or products with significant implications for the environment. Similarly, firms which actively seek to reduce the risk of future environmental liabilities and to foster an image as being environmentally friendly are more likely to invest in innovative activities with respect to environmental issues, while non-adopters have insufficient information about their own environment-related practices to behave in an innovative manner. Thus, environmental accounting is expected to assist firms identify potentially valuable new opportunities for investment in environmental R&D, which non-adopters would not identify.

Assessment of all of these hypotheses raises significant data problems. In particular, measuring innovation is a difficult issue. In this chapter, due to the availability of the data, we measure environmental technological innovation by its input: expenditures on environmental research and development (R&D). Some studies have used the number of successful patent applications as an alternative measure. This has the advantage of being an output variable. However, this method has been criticized since the relative importance of each patent differs. While the same could be said of R&D expenditures, it is likely to be true to a lesser extent. Thus, one may argue that the use of R&D information is not inferior to the use of the number of patents (see Griliches 1990 for a discussion).

The purpose of our chapter is to explore the determinants of implementation of environmental R&D, examining the three hypotheses set out above. Thus, the role of policy stringency on investments in environmental R&D is examined. In addition, we focus on how public environmental policy design affects environmental R&D. And finally, we analyse the effect of environmental management (specifically accounting) on environmental R&D. In addition to testing aspects of all three hypotheses set out above, the methodological contribution of our chapter is threefold.

Firstly, environmental R&D is used as the dependent variable. This is more appropriate than total R&D in the analysis of the relationship between policy stringency and instrument choice in innovative behaviour. A more stringent environmental policy may result in an increase in environmental R&D, and a decrease in R&D focused on other objectives, and thus may not affect total R&D – that is, there may be crowding out. Therefore, if total R&D rather than environmental R&D is the focus of the analysis, as in the previous studies, this may result in misleading conclusions. However, the use of environmental R&D in the analysis means that little can be said about the overall innovation gains associated with the policy measure.

Secondly, since we take the adoption of environmental accounting systems into consideration in analysing the determinants of environmental R&D activities, the impact of environmental policy on environmental R&D is decomposed into the direct impact and the indirect impact. More specifically, in addition to the direct effect of environmental regulation on environmental R&D, environmental regulation may have an indirect effect on environmental R&D through its effect on the adoption of appropriate environmental management tools (that is, an environmental accounting system). If the adoption of an environmental accounting system is not taken into consideration, the estimated parameters of an environmental R&D model may be biased.

And finally, a third feature of our study is to use a facility-level data set to examine effects on environmental technological innovation. Manufacturing firms with high environmental R&D expenditures often have numerous facilities producing different manufactured goods. Generally, however, environmental policies target individual manufacturing facilities. If one uses industry-level or firm-level data, it is difficult to identify whether technology-based standards, performance-based regulation or economic instruments are imposed. This is because a firm typically has several facilities and each facility may face different types of policy instruments. Use of facility-level data can overcome this problem to some extent. This allows for more precise analysis of the relationship between environmental policy instruments and environment-related technological innovation.

The rest of the chapter is organized as follows. The following section provides a literature review. Section III provides an overview of the data. Section IV presents an econometric analysis model of environmental R&D and environmental accounting system with the estimation results. Section V summarizes the conclusion of this chapter.

II. REVIEW OF THE EMPIRICAL LITERATURE

Following from the discussion above, the literature review is structured in terms of the following three sets of issues: the effect of public policy stringency on innovation; the effect of instrument choice on innovation; and the effect of management practices on innovation.

Policy Stringency and Innovation

Several empirical studies on the relationship between environmental policy and technological innovation have been undertaken. Lanjouw and Mody (1996) examined the relationship between the number of patents granted and the environmental policy strength, measured in terms of pollution abatement expenditures at the macroeconomic level for Japan, US and Germany. They found that pollution abatement cost affects the number of patents successfully granted with a one- to two-year lag. However, their study is not entirely satisfactory because other factors that are likely to affect technical innovation were not controlled for.

Using US industry-level data, Jaffe and Palmer (1997) extended Lanjouw and Mody's study by incorporating various confounding factors in the analysis. As a measure of innovation, they examined R&D expenditures and the number of patents granted. The study confirmed that environmental regulation increases R&D expenditures. But it did not support the hypothesis that the number of patents increased in response to environmental regulation. They also stressed the necessity to examine the narrow version of the Porter Hypothesis: the relative strength of the effects of flexible versus prescriptive environmental policy regulation regarding environmental innovation.

Brunnermeier and Cohen (2003) used US manufacturing industry data and empirically analysed factors that determined environmental technological innovation. They paid close attention to the fact that emission reduction pressures come not only from domestic regulatory authorities, but also from the international regulatory and market environment. As indicators of emission reduction pressures, they use pollution abatement costs and the number of inspections undertaken by the direct regulatory institutions. As a measure for environmental innovation, they used counts of environment-related patents. They found that environmental innovation becomes more active as pollution abatement expenditure increases. Moreover, they found that international competition stimulates environmental innovation. However, the effect of inspections was not confirmed.

Instrument Choice and Innovation

From the empirical perspective, only a few studies have so far been undertaken on the role of different policy instruments on innovation. Kerr and Newell (2003) studied environmental regulations related to lead concentration contained in gasoline in the US. They analysed the effect of this regulation on technological innovation. In support of the evidence cited above, it was found that new technology is adopted as the stringency of regulation increases. It was also found that the introduction of a tradeable permit system promotes the adoption of new technology, and that generally policies using market incentives stimulate new technology in a more significant manner than policies which do not provide market incentives.

Jaffe and Stavins (1995) examined the role of different policy measures on technology diffusion, although not innovation *per se*. Looking at building insulation practices they found that subsidies for energy conservation have a stronger influence than energy taxes, and that direct regulations (such as building codes) had little effect. However, they took care to emphasize that the greater role of subsidies in encouraging diffusion of insulation practices is not necessarily an argument in favour of their use, not least because the negative scale effects in terms of energy consumption may outweigh the benefits in terms of increased insulation.

Based upon an empirical analysis of German manufacturing facilities, Hemmelskamp (1999) was unable to draw firm conclusions about the role of different environmental policy instruments on innovative behaviour. While economic instruments (taxes in this case) may have positive effects on product innovation, standards appear to have a stronger influence in other areas such as energy consumption. Generally, he stresses the importance of looking at both sectoral characteristics and organizational factors.

Popp (2003) examined the effects of the introduction of the tradable permit system for SO_2 emissions as part of American Clean Air Act amendments on the technological efficiency of flue-gas desulphurization. Comparing the removal efficiency of flue-gas desulphurization before and after the introduction of the emission trading system, he finds that the emission trading programme induced innovation.

Management Practices and Innovation

Evidence with respect to the links between management practices and environment-related technological innovation is limited. However, a number of recent empirical studies find that the firm's decision-making with respect to a number of environmental areas is not statistically well explained by econometric models in which the role of organizational factors is not assessed (see DeCanio 1998; DeCanio and Watkins 1998; DeCanio et al. 2000; Nakamura et al. 2001). While such studies do not focus on innovation *per se*, the insights gained are of interest in the context of the present study.

DeCanio (1998) analysed data from one of the US Environmental Protection Agency's voluntary pollution prevention programmes (Green Lights). He found that both the level and variation in returns to investments in lighting upgrades cannot be explained by standard economic models. The analysis of the data strongly support the conclusion that organizational and institutional factors are important determinants of firms' investment behaviour. This evidence supports the view that impediments that are internal to private and public organizations discourage the implementation of profitable investments. He concluded that variables representing such impediments should be considered when assessing such programmes.

DeCanio et al. (2000) used network models to explore the determinants of diffusion of profitable innovations, with a focus on the role of organizational structures, and particularly the effect of organizational structures on the nature of communication within the facility. They found that the organizational structure of the firm was a crucial element in the diffusion of technological innovations since it affects the flow of information between agents. They argued that an inaccurate evaluation of the effects of policy changes would result from leaving out important determinants such as organizational structure.

Nakamura et al. (2001) studied the determinants of large Japanese manufacturers to incorporate environmental goals in their decisions, to adopt ISO 14001, and to become early adopters of ISO 14001. Two sets of models were applied – models based on an assumption of profit maximization, and models based on the assumption of utility maximization. The objective was to test whether managers' values, attitudes and beliefs influence firms' decisions. They found that the explanatory powers of the model increased by incorporating variables affecting the utility of managers into the traditional models based on profit maximization. In particular, they found that the environmental values, beliefs and attitudes of key managers were significant determinants of environmental commitments.

These studies appear to support the view that organizational factors, management practices and even the personal values of managers can play a determinant role in firms' decision making with respect to environmental matters. In some cases, factors which are internal to the firm may discourage the realization of investment opportunities which results in both financial and environmental gains.[1] Therefore the firm's specific characteristics representing the organizational structure of the firm and its management practices should be considered in order to improve the analysis of the firm's behaviour.[2]

III. THE SURVEY AND THE DATA

Drawing upon data collected as part of the OECD project this chapter casts further light on the aforementioned issues. Consistent with the discussion in the previous sections, in this study we examine three main hypotheses:

Hypothesis 1: *Policy stringency encourages investment in environmental R&D.*

Hypothesis 2: *Flexible environmental policy instruments promote environmental R&D to a greater extent than prescriptive instruments.*

Hypothesis 3: *The introduction of an environmental accounting system promotes environmental R&D.*

While Chapter 1 provides an overview of the OECD database as a whole, the main descriptive results for the primary variables of interest to this chapter are reviewed below.

Overall, 9.3 per cent of facilities report having invested in environment-related research and development. Figure 4.1 shows the proportion of facilities by country. Norway has the highest percentage with just under 15 per cent reporting having done so, while in the case of Germany it is only 3.6 per cent. For four of the seven countries (France, Canada, Japan and the United States), the proportion is approximately 10 per cent.

Figure 4.2 shows the proportion of facilities with environment-related R&D budgets according to facility size. As can be seen clearly, larger facilities (>500 employees) are more likely to have undertaken such investments, with almost 20 per cent reporting having done so, while the figure is less than 10 per cent for facilities with less than 250 employees. In the sample as a whole, the average size of facility responding affirmatively had over 720 employees, while for those who had responded negatively the figure was less than 300.[3]

The sectors with the highest percentage of facilities responding that they had environment-related R&D budgets were recycling (25 per cent); petroleum, coke and other fuel products (14 per cent); chemicals and chemical products (13 per cent); motor vehicles (12 per cent); electrical machinery (12 per cent); rubber and plastics (11 per cent); metal products (10 per cent); and non-metallic mineral products (10 per cent).

In the survey, we also elicited information on R&D expenditures used for environmental purpose, both as a percentage of total R&D and in value terms. Table 4.1 provides the mean of environmental R&D expenditures of facilities with environmental R&D activities for each country, as well as the

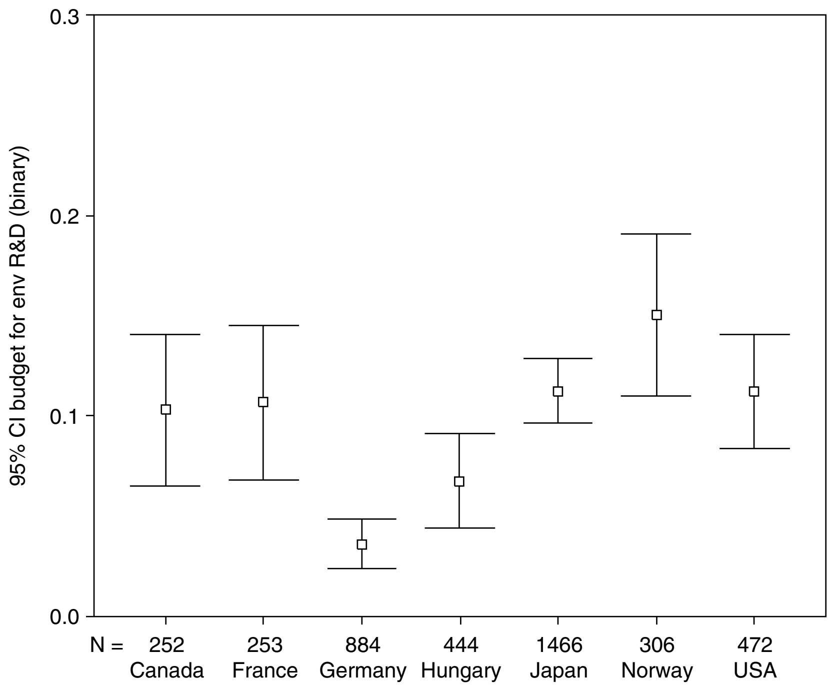

Figure 4.1 Proportion of facilities with environment-related R&D by country

mean reported percentage of total R&D for environmental purposes (for those facilities which provided non-zero values).

The reliability of the R&D expenditure data can be examined by comparing the OECD survey with data collected as part of the Survey of Research and Development 2002,[4] which has been conducted in Japan for more than a decade. In the Japanese Survey of Research and Development 2002, firms are requested to provide information on R&D expenditures from the past year from 31 March 2002 or some other settling day in the region of this date. The survey was targeted at companies and special corporations with capital greater than 10 million yen. Approximately 13 000 firms are subjects of the survey and approximately 83 per cent replied.

As in our study, respondents were requested to provide information on the specific purposes of the research expenditures, including environmental conservation. Among 4312 facilities which replied to this question, 8.4 per cent or 360 facilities had environment-related research expenditure. In the OECD survey the corresponding figure was 12 per cent. Environment-related R&D expenditures accounted for 3.4 per cent of total R&D

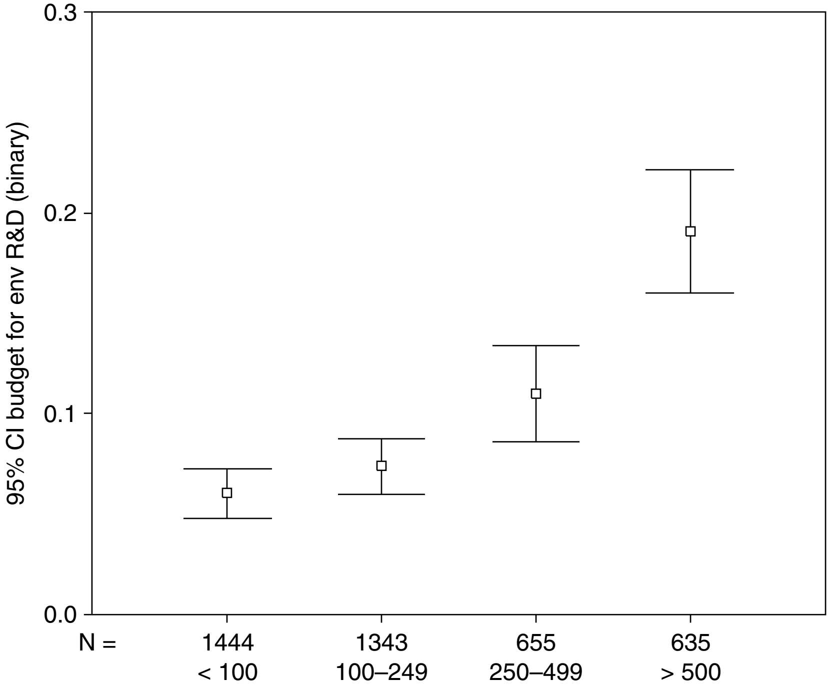

Figure 4.2 Proportion of facilities with environment-related R&D by facility size

Table 4.1 Environmental R&D expenditures

Country	SDRs	% of R&D
Canada	4 865 747	13.23
France	1 563 251	20.35
Germany	3 190 587	17.38
Hungary	578 379	19.05
Japan	4 669 871	20.46
Norway	825 745	35.68
USA	2 921 721	16.01

expenditure for the manufacturing industry. In the OECD survey the corresponding figure was 16.6 per cent. Thus the sample used in this analysis is significantly upward-biased. However, the figure for the OECD survey only includes facilities which provided non-zero values. Nonetheless, given

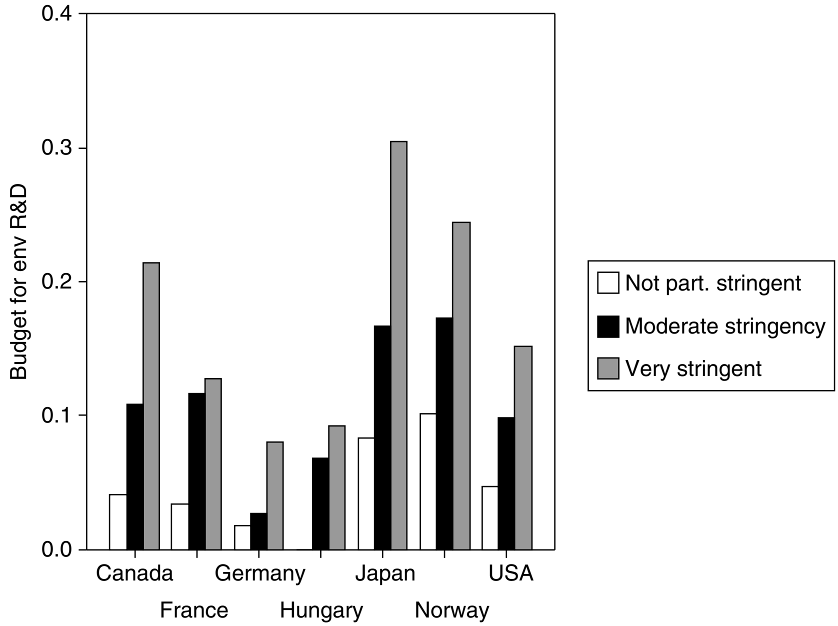

Figure 4.3 Perceived relative stringency of environmental policy regime and budget for environmental R&D

the environmental focus of the questionnaire in the OECD survey there is likely to be some selection bias.

Data were also collected on the nature of the environmental policy regime. Most directly, respondents were requested to give an indication of their perception of the degree of stringency of the policy regime to which they were subject. Figure 4.3 provides a comparison of the different perceptions of the policy regime and the percentage of facilities which report having a budget for environment-related R&D. For all countries, the likelihood of investing in environment-related research and development increases with perceived policy stringency.

In addition, figures on the mean number of times that facilities report having been inspected varies markedly by country. As noted in Chapter 1, half of all facilities in Japan report that they were not inspected in the last three years. Overall, somewhat more than 5 per cent of facilities report having been inspected more than ten times in the last three years. The relationship between frequency of inspections and the likelihood of investing in environment-related research and development is less clear than was the case for perceived policy stringency (see Figure 4.4).

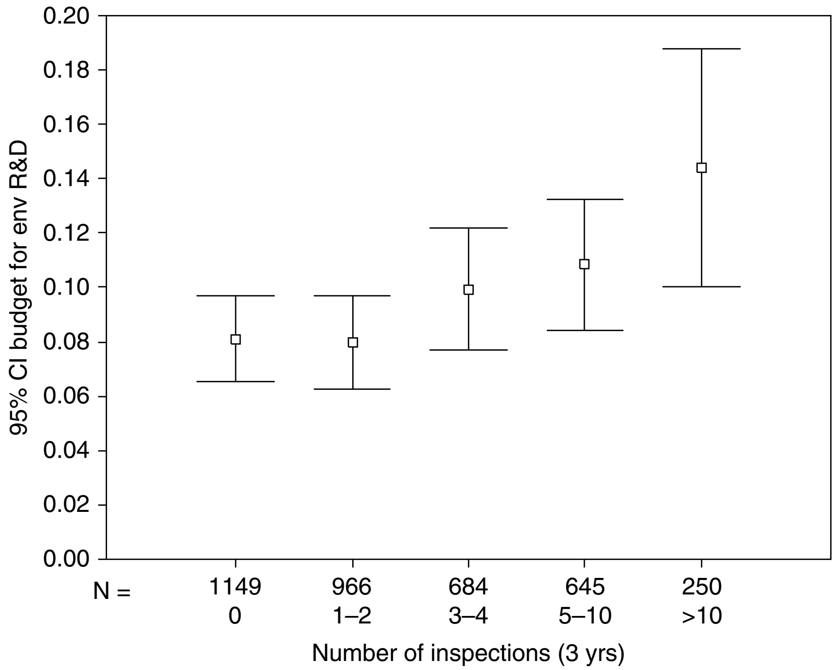

Figure 4.4 Reported frequency of inspections against budget for environmental R&D

Table 4.2 Presence of different environmental policy instruments and budget for environmental R&D

	Technology standard	Performance standards	Input tax	Pollution tax
Budget (%)	9.66	9.84	9.62	9.90
No budget (%)	8.37	7.02	7.88	7.25

Table 4.2 gives an indication of the relationship between a sub-set of different types of policy instrument and implementation of environment-related R&D budgets. In all cases the presence of the instrument has a positive effect on investing in environment-related R&D. However, the effect is least pronounced for the most prescriptive type of policy instrument (technology-based standards).

The relationship between environmental accounting and environment-related research and development is given in Figure 4.5. At the country level

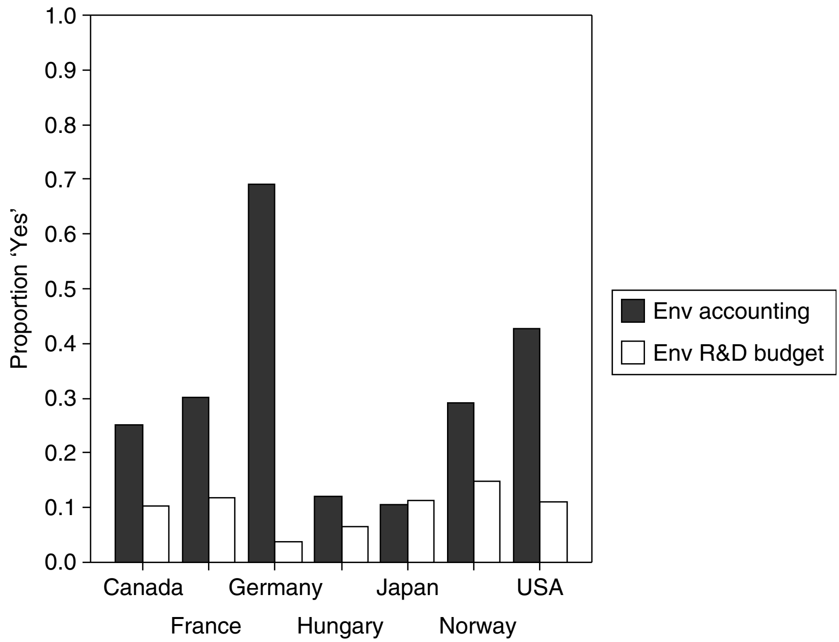

Figure 4.5 Percentage of facilities with environment-related R&D budgets and environmental accounting

it is striking that there is little apparent correlation between the reported investment in environment-related research and development, and environmental accounting. For instance, Germany has the highest percentage for the former but the lowest for the latter. However, as the empirical results presented below indicate a simple bivariate comparison can be a misleading indicator of the underlying relationship.

In addition to this data, information on firm and facility characteristics and market structure were included in the estimation model. Descriptive statistics on the variables used in the models are presented in Annexes B and C below. The expected signs are discussed in section IV below.

IV. ECONOMETRIC ANALYSIS OF ENVIRONMENTAL R&D EXPENDITURES

In order to test the hypotheses set out above, we estimate a reduced form model of facilities' decisions with respect to environmental R&D. The models are estimated on the cross-section of data for a single time period.

This necessitates a degree of caution being exercised in the interpretation of the results. The facilities make the decision to implement R&D with a long-term perspective. In this sense, the cross-sectional data might not capture the facilities' planning horizon. However, the variables used in our analysis, such as policy stringency, policy instruments, market status, stakeholders and management practices, are expected to be relatively stable over short periods. In addition, with regards to other variables which are more variable – such as sales increase and profitability – information was obtained on performance over the last three years. Hence, the limitation of our data set is not expected to be critical.

Tobit Estimation

In the sample used in the analysis, a considerable number of the facilities had no environmental R&D expenditures whatsoever. Namely, the dependent variable was zero for a large number of facilities. Thus, by assuming the error term is normally distributed, a Tobit model is estimated to obtain the coefficients. Therefore, we regress environmental R&D expenditures on the various factors as specified in the following equation:

$$\begin{aligned} ERD\_Exp_i = {} & \theta_0 + \theta_1 EA_i + \theta_2 P_i + \theta_3 IF_i + \theta_4 TS_i + \theta_5 PS_i + \theta_6 IT_i + \theta_7 PT_i \\ & + \theta_8 TA_i + \theta_9 Listed_i + \theta_{10} Employee_i + \theta_{11} SG_i + \theta_{12} BF_i \\ & + \theta_{13} MF_i + \theta_{14} MC_i + \theta_{15} GM_i + \sum_{j=1}^{6} \mu_j^0 cd_i^j + \sum_{k=2}^{10} \phi_k^0 sd_i^k + \varepsilon_i^0 \end{aligned} \tag{4.1}$$

where ERD_Exp_i captures R&D expenditures for environmental purposes. The explanatory variables are defined and discussed below.

First, EA_i is a dummy variable reflecting whether an environmental accounting system has been adopted at facility i, with $EA_i = 1$ if the facility adopts an environmental accounting system and $EA_i = 0$ otherwise. As noted above, an environmental accounting system is likely to help the facility which adopts it to know its production possibilities better. Thus, the adopter is more likely to find the opportunities for environmental innovation better than non-adopters, and is thus more likely to invest in research and development. Therefore, the coefficient of EA_i is expected to be positive.

As previous literature has suggested, firms are more likely to incur expenditures on environmental R&D activities if they face a stringent environmental policy regime. We use two variables to reflect the strength of environmental policies. The first variable (P_i) is a measure of the 'subjective perception' of the strength of environmental policy. It is a dummy variable that takes 1 if the respondent at facility *i* perceives the facility is subject to a stringent environmental policy regime, and 0 otherwise. The coefficient of this variable is also expected to be positive. Another variable designed to reflect the stringency of environmental policy is IF_i, the frequency of inspections on environmental matters by the relevant public authority in the last three years. Previous literature such as Brunnermeier and Cohen (2003) has also used inspection frequency as a proxy for the policy stringency.

In order to examine the effects of different policy instruments, we include dummy variables that capture the reported applicability of five different environmental policy instruments. In the survey, respondents are asked whether each environmental policy instrument is 'not important', 'moderately important', 'significantly important' or 'not applicable' in terms of impacts on the production process. We include a dummy variable for technology-based standard (TS_i) which takes on a value of 1 if the facility faces policy instruments which could be characterized as technology-based standards and 0 if they said it was not applicable. Similarly, the applicability of more flexible performance standards is captured by a dummy variable (PS_i). Economic policy instruments such as pollution taxes and input taxes are considered to be more flexible (giving the facility manager more discretion) than performance standards and, of course, technology standards. We include dummy variables to represent the applicability of input taxes (IT_i) and pollution taxes (PT_i) to facility *i*.

The 'narrow' version of the Porter Hypothesis implies that more flexible policy instruments promote more innovation, but prescriptive instruments do not. If the narrow version of the Porter Hypothesis holds, performance standards should increase incentives to invest in environment-related R&D to a greater extent than technology-based standards. Thus, the coefficient of the performance standard is expected to be positive and greater than the coefficient of the technology-based standard in absolute value. We also expect the sign of coefficients for the pollution tax and input tax variables to be positive, and the absolute values to be greater than the coefficients for technological and performance standards.

Another environmental policy instrument included in equation (4.1) represents the presence of public technical assistance programmes (TA_i). Since the provision of technical assistance is likely to reduce the costs of research and development, the coefficient is expected to be positive. However, it is also possible that public technical assistance will reduce the need for private investment in environmental research and development, which would be reflected in a negative sign.

In addition to the public policy variables a number of important variables affecting either the supply or demand of environmental research and development are included in the estimated models. Facility size is potentially an important factor affecting decisions on R&D. In particular there may be a minimum efficient scale for undertaking R&D. As such, if the size of the facility is small, it may not have enough personnel to conduct environmental R&D in an efficient manner. We use $Employee_i$ to measure the size of facilities by the number of employees at facility *i*. The coefficient is expected to be positive. In addition, given that such economies of scale may be realized across facilities, the facility's decision to invest in environmental R&D is likely to depend on the size of the firm to which the facility belongs. Therefore, we include a dummy variable, MF_i which takes a value of 1 if the facility is part of a firm which has multiple facilities.

The facility's recent commercial performance may also affect the decision to invest in environmental R&D. For instance, it has long been argued that research and development is difficult to finance through capital markets, and thus facilities often do so out of retained earnings (see Jaffe et al. 2003). As such, facilities with weak recent commercial performance are more likely to face liquidity constraints and may have difficulty financing environmental R&D. A dummy variable (BP_i) is constructed to take the value of 1 if the facility's revenue has been insufficient to cover costs in the past three years and the coefficient is expected to be negative. A facility with growing sales is likely to be more innovative since it can expect return on its R&D investment from the growing demand. Thus, the facility with growing sales has more incentives to conduct environmental R&D. We include a dummy variable (SG_i) that takes 1 if the value of shipments from the facility increased in the last three years.

As is well documented in the literature, the structure of the market can be an important factor in explaining the extent of innovation (see Scherer 1982; Griliches 1989; Acs and Audretsch 1989; Kraft 1987 for discussions). A number of empirical studies have used market concentration ratios to try and explain firms' R&D activities. We include a dummy variable (MC_i) that takes the value of 1 if the number of other firms with which the facility competes on the market is less than five. The spatial scope of the market may also affect the facility's decision on environmental R&D. For example, a facility with the scope of the global market is more likely to have incentives to be innovative than a facility with a local or regional market. If a new environmental regulation is introduced in countries where the product is exported, the facility may have to change the product to comply with the regulation. For example, a recent regulation on the use of chemicals is known to have impacts on the decisions of Japanese manufactures exporting to European countries. Thus, we construct a dummy variable (GM_i) that takes the value of 1 if the facility's scope of the market is global in nature.

Facilities which are part of firms listed on the stock exchange may face pressures to be environmentally correct due to the visibility and transparency associated with being listed. A stock market listing may also facilitate access to capital to finance environment-related research and development. Thus, we include a dummy variable ($Listed_i$) that takes the value of 1 if the firm of facility i is listed on a stock market, and the coefficient is expected to be positive for the two reasons noted above.

Environmental R&D expenditures may differ by type of the industry which the facility belongs to, since both technological opportunities and demand may vary systematically across sectors. Thus, we include industry dummies (sd_i^k) for each industry for $k = 1,\ldots,9$. The industries are classified as aggregates of the ISIC two-digit classification into the following sectors: (1) food products, beverages and tobacco; (2) textiles, textile products, leather and footwear; (3) wood and wood products and furniture; (4) pulp, paper, paper products, printing and publishing; (5) chemicals, fuel, rubber and plastic products; (6) other non-metallic mineral products; (7) basic metals and fabricated metal products; (8) machinery, electrical and optical equipment; (9) transport equipment; (10) recycling. We use the food industry as the reference class in the models estimated. (See Table 1.2 in Chapter 1 for corresponding ISIC classifications.)

And finally, there may be attributes of individual countries distinct from the variables noted above which affect the propensity to innovate (that is, education systems, cultural factors, and so on). Thus some countries may be more innovative in environmental manners than others, even after controlling for the effects of other various factors. In order to test for this difference by country, we also include country dummies, cd_i^j for $j = 1,\ldots,6$. These dummies are constructed for the following countries; Germany, Hungary, Japan, Norway, France and Canada. The reference case is the United States.

Unobservable characteristics of facilities may also have influence on the facilities' decisions on environmental R&D expenditure. The error term, ε_i^0, captures these unobservable characteristics. The unknown parameters, $(\theta_0,\ldots,\theta_{15}, \mu_1^0,\ldots,\mu_6^0, \phi_2^0,\ldots,\phi_{10}^0)$, are to be estimated.

In principle, this model can be applied across all facilities. However, while the total size of the database includes observations from almost 4200 facilities, it must be emphasized that with respect to the issue of environmental research and development there were many missing observations in the database. As such, the sample size used in the estimation was 1585. The descriptive statistics for the dependent and explanatory variables for these observations are shown in Appendix 4B. The principal results are shown in Table 4.3. The log likelihood is −696.1 and the Wald statistic is 203.2. Therefore, the hypothesis that all the coefficients except the constant term are 0 is rejected at the 1 per cent level.

The coefficient reflecting perceived policy stringency is positive and significant. Thus, it is confirmed that the stringent environmental policy

Table 4.3 Estimation results of Tobit model

Categories	Variables	Coefficients	Z-Value
Policy stringency	P_i	15.30***	2.89
	IF_i	−0.197	−0.80
Policy instruments	TS_i	1.119	0.19
	PS_i	−9.882	−1.37
	IT_i	9.124	1.26
	PT_i	−7.251	−1.09
	TA_i	8.362*	1.68
Environmental management	EMS_i	4.226	0.89
	EA_i	21.01***	3.87
Firm/facility characteristic	$Employee_i$	0.011***	11.11
	SG_i	8.661*	1.87
	BF_i	−0.059	−0.01
	MF_i	−0.761	−0.16
Market characteristic	MC_i	−1.461	−0.30
Stakeholders	$Listed_i$	3.489	0.62
	GM_i	−0.840	−0.18
Country dummies	Germany	−23.87***	−2.76
	Hungary	−2.980	−0.32
	Japan	25.77***	3.22
	Norway	14.33	1.42
	France	−1.649	−0.15
	Canada	−5.486	−0.53
Sector dummies	Textiles	3.483	0.28
	Wood	3.592	0.29
	Pulp	−0.752	−0.07
	Chemical	−4.142	−0.45
	Other non-metallic Mineral	13.49	1.18
	Basic Metals	4.541	0.53
	Machinery	−4.540	−0.51
	Transport Equipment	6.100	0.58
	Recycling	6.296	0.38
	Constant	−87.79	−6.55

Notes:
***, ** and * indicate that the coefficient is statistically significant from 0 at the 1%, 5% and 10% level respectively.
Dependent variable: R&D expenditure used for environmental purposes.

induces more R&D expenditure for environmental purposes. Conversely, the effect of inspection stringency is not significant. Due to concerns of potential multicollinearity the model was re-estimated without inclusion of the policy stringency variable, and inspection frequency remained insignificant.

As to specific policy instruments, we found that technical assistance increases the expenditure on environmental R&D with a significance level of 10 per cent. This result is intuitive since technical assistance is often closely related to technology choices by definition. However, we did not find that other policy instruments affect the decision to invest in environmental R&D. Therefore, in this model, we could not find a support for Hypothesis 2 (flexible versus prescriptive instruments).

Among firm and facility characteristics, the coefficient for the sales growth variable (SG_i) is positive and significant at the 10 per cent level. This result implies that firms facing growing demand are more likely to spend on environmental R&D. In addition, the effect of facility size is positive and statistically significant. Both of these results are consistent with expectations.

The coefficient for the variable reflecting the adoption of environmental accounting is positive and significant. However, the effect of a more general environmental management system is not significant. One must note a potential endogeneity problem with the inclusion of the variable for the adoption of an environmental accounting system. Those firms that have adopted an environmental accounting system may have done so because the management of the firms more generally prefers environmentally friendly practices. This environmental consciousness is presumably captured in the error term of the equation (4.1). In this case, the adoption of the environmental accounting system may be correlated with error term of the equation (4.1). Consequently, there is a possibility of bias on the estimates of the effects of an environmental accounting system.

Another aspect of the estimation results warrants comment. Although Japanese firms are accustomed to saying what proportion of R&D expenditure is devoted for environmental purposes as shown in the previous section, firms in other countries may not be so confident in categorizing their R&D expenditures. Even among Japanese respondents, we found that the OECD survey's result on environmental R&D expenditure is upward-biased. Thus, it is worth examining whether environmental R&D is conducted at all, rather than expenditure used for environmental R&D.

Bivariate Probit Estimation

In the last subsection, we reported on the results of a Tobit model of environmental R&D expenditures. However, we noted two potential problems of the Tobit model: measurement error with respect to environmental R&D

expenditures, and possible endogeneity of the adoption of environmental accounting.

One way to deal with the measurement issue is to examine whether or not environmental R&D is conducted at a facility at all, rather than the level of expenditure. In this way, we can avoid possible measurement error of the R&D expenditure for environmental purpose, albeit at the cost of a loss of information. Interestingly, independent estimation of a probit model on the decision to invest in environmental R&D found that more prescriptive policy measures (technology-based standards and input bans) had a negative influence on the likelihood of undertaking such investments (see Johnstone and Labonne 2005).

As noted, in addition to the measurement issue, there is a potential problem of endogeneity related to the adoption of an environmental accounting system.[5] In order to deal with the endogeneity problem, we simultaneously estimate decisions on environmental R&D and the adoption of an environmental accounting system. Thus, in this subsection, we estimate a reduced form model of facilities' decisions on environmental R&D and an environmental accounting system. We will explain the models for both decisions, respectively.

First, we will describe the decision with respect to environmental R&D. Facilities' decisions on whether they conduct environmental R&D or not depend on various factors. We examine the following equation:

$$
\begin{aligned}
Y_i^* = {} & \beta_0 + \beta_1 EA_i + \beta_2 P_i + \beta_3 IF_i + \beta_4 TS_i + \beta_5 PS_i + \beta_6 IT_i + \beta_7 PT_i \\
& + \beta_8 TA_i + \beta_9 Listed_i + \beta_{10} Employee_i + \beta_{11} SG_i + \beta_{12} BF_i \\
& + \beta_{13} MF_i + \beta_{14} MC_i + \beta_{15} GM_i + \sum_{j=1}^{6} \mu_j^1 cd_i^j + \sum_{k=2}^{10} \phi_k^1 sd_i^k + \varepsilon_i^1 \qquad (4.2)
\end{aligned}
$$

where facility i conducts environmental R&D ($ERD_i = 1$) if $Y_i^* > 0$ and the facility does not conduct R&D ($ERD_i = 0$) if $Y_i^* \leq 0$.

The explanatory variables of the environmental R&D equation are the same as in equation (4.1) since the reasoning behind the discrete environmental R&D decision is expected to be the same as that with respect to the decision on the level of environmental R&D expenditures. Unobservable characteristics of facilities may also have influence on the facility's decision on environmental R&D. The error term, ε_i^1, captures these unobservable characteristics. The unknown parameters, $(\beta_0, \ldots, \beta_{15}, \mu_1^1, \ldots, \mu_6^1, \phi_2^1, \ldots, \phi_{10}^1)$, are to be estimated.

The model describing the facility's decision on the adoption of environmental accounting systems is set out below. We estimated the following model:

$$\begin{aligned} EA_i^* = {} & \gamma_0 + \gamma_1 P_i + \gamma_2 IF_i + \gamma_3 TS_i + \gamma_4 PS_i + \gamma_5 IT_i + \gamma_6 PT_i + \gamma_7 TA_i \\ & + \gamma_8 Employee_i + \gamma_9 SG_i + \gamma_{10} BF_i + \gamma_{11} MF_i + \gamma_{12} MC_i \\ & + \gamma_{13} Listed_i + \gamma_{14} GM_i + \gamma_{15} EMS_i + \gamma_{16} QM_i + \gamma_{17} SMS_i \\ & + \gamma_{17} FCA_i + \gamma_{18} MAS_i + \gamma_{19} PCS_i + \gamma_{20} IRP_i \\ & + \sum_{j=1}^{6} \mu_j^2 cd_i^j + \sum_{k=2}^{10} \phi_k^2 sd_i^k + \varepsilon_i^2 \end{aligned} \tag{4.3}$$

where facility i implements an environmental accounting system ($EA_i = 1$) if $EA_i^* > 0$ and the facility does not ($EA_i = 0$) if $EA_i^* \leq 0$.The notation for regressors is the same as in (4.1).

An environmental accounting system is thought to give managers a better grasp of the facility's operations and environmental impacts. In other words, the environmental accounting system is expected to help facility managers to identify an efficient way to comply with environmental regulations. Thus, if a facility faces a stringent environmental policy regime, it will have a greater incentive to adopt an environmental accounting system. Thus, the coefficients for policy stringency (P_i) and inspection frequency (IF_i) are expected to be positive.

While the introduction of an environmental accounting system helps facilities to identify efficient ways to comply with environmental regulations, different types of policy instruments are likely to have different effects on the benefits of the adoption of environmental accounting system. If a technology-based standard is imposed on a facility, it has to follow the abatement strategy set out by the regulator. Thus, the technology-based standard will not provide strong incentives to seek out more efficient compliance strategies. On the other hand, if flexible policy instruments are applied, there are alternative options which can be adopted for the choice of methods of compliance. Facilities may benefit from the adoption of an environmental accounting system since it helps facilities to identify the most cost-effective alternatives. Therefore, the coefficients for the variables reflecting the presence of performance standards, input taxes or pollution taxes are expected to be positive.

If the firm to which facility i belongs is listed on the stock exchange, it is likely to face greater pressure to be environmentally innovative both in terms of technology and in terms of organization. Thus, listed firms and their facilities are more likely to adopt environmental accounting systems. Hence, the coefficient for $Listed_i$ is expected to be positive in the environmental accounting equation.

Facilities with an environmental management system are likely to have personnel designated with responsibility for environmental matters, or a specific department in charge of environmental matters. Further, they may have systems in place to collect information on a firm's environmental impacts. As such, it is expected that a facility is more likely to adopt an environmental accounting system if it has an environmental management system since this will reduce the costs of its introduction. It may also increase the benefits of doing so, since it will have an improved information base upon which to apply innovations. Thus, we included a dummy variable EMS_i that takes on a value of 1 if facility i has adopted an environmental management system.

The adoption of an environmental accounting system is also likely to be influenced by other existing management practices, even if they are not explicitly environmental in nature. Thus, we include the following dummy variables to capture the presence of general management practices: QM_i for a quality management system; SMS_i for a health and safety management system; FCA_i for full-cost or activity-based accounting; MCA_i for a management accounting system; PCS_i for a process or job control system; and IRP_i for inventory or materials requirement planning. The coefficients for these dummies are all expected to be positive. Among these management practices, full-cost or activity-based accounting and a management accounting system are considered to be potential complements to an environmental accounting system. Country and sector dummies are included for reasons analogous to those discussed above with respect to the R&D equation.

And finally, unobservable characteristics of facilities may also have influence on a facility's decision on environmental accounting system. The error term, ε_i^2, captures these unobservable characteristics. The unknown parameters, $(\gamma_0,\ldots, \gamma_{20}, \mu_1^2,\ldots, \mu_6^2, \phi_2^2,\ldots, \phi_{10}^2)$, are to be estimated. Following the literature on the estimation of discrete choice models, we assume that the unobservable error terms follow a normal distribution. If a facility's decisions with respect to the implementation of an environmental accounting system and investment in environmental R&D are independently determined, then we can estimate the firm's decisions equations (4.2) and (4.3) separately as probit models. However, if the decisions are correlated, that is, the two unobservable errors are correlated ($Cov(\varepsilon_i^1, \varepsilon_i^2) \neq 0$), then the error term, ε_i^1, and the adoption of environmental accounting system, EA_i, are correlated. Thus, the maximum likelihood estimation of the probit equation (4.2) cannot give consistent estimators of the parameters.

To deal with this potential endogeneity problem, we estimate a bivariate probit model of equation (4.2) and (4.3) by assuming the following distribution:

$$\begin{pmatrix} \varepsilon_i^1 \\ \varepsilon_i^2 \end{pmatrix} \sim N(0,V) \text{ where } V = \begin{pmatrix} 1 & \sigma_{12}^2 \\ \sigma_{12}^2 & 1 \end{pmatrix}.$$

The variances of the normal distribution are assumed to be 1 for the purpose of identification.

In principle, this model can be applied across all facilities as well. Again, it must be emphasized that with respect to the decision concerning environmental research and development there were many missing observations in the database. Moreover, variables on management practices have missing observations. Therefore, the sample size used in the estimation was 1454. The descriptive statistics for the dependent and explanatory variables for these observations are shown in Appendix 4C.

The estimation results of the bivariate probit model are set out in Table 4.4. The log likelihood is -1019.7 and the Wald statistics is 632, and thus, the hypothesis that all coefficients except the constant term are 0 is rejected at the 1 per cent level. These results confirm the validity of the model.

In order to establish whether the two dependent variables were determined endogenously, we tested whether the covariance of the error terms is 0 by the likelihood ratio test. The hypothesis is rejected at the 1 per cent level since the likelihood ratio is 10.1. Thus, the model of the environmental R&D equation cannot be estimated by a single equation of the probit model. To deal with this problem of endogeneity, one must estimate the two equations together.

First, we examine the estimation results of equation (4.3) which explain the adoption of an environmental accounting system. The estimated coefficients are shown in the middle two columns in Table 4.4. The coefficients of the two policy stringency variables are both positive. The coefficient of the inspection frequency variable is different from 0 at the 5 per cent significance level. Thus, it is confirmed that the stringent environmental policy promotes the adoption of an environmental accounting system.

The presence of different policy instruments in the policy regime is also found to be important. The coefficient of effluent tax is positive and significantly different from 0 at the 1 per cent level. On the other hand, the presence of a prescriptive instrument such as a technology-based standard is not effective in promoting the adoption of the accounting system. These results support the hypothesis that flexible instruments promote environmental accounting but prescriptive instruments do not.

The size of a facility is important in the decision to adopt an environmental accounting system. The coefficient of the variable $Employee_i$ is positive and statistically significant at the 1 per cent level. The size of the firm is also important. The coefficient of MF_i is positive and statistically significant at the 10 per cent level. These results show that facilities are less likely to introduce environmental accounting systems unless the facility (and the firm of which it is a part) is large enough.

As to management practices, we obtained expected results. The coefficients of EMS_i and QM_i are positive and statistically significant. The facilities with

Table 4.4 Estimation results of bivariate probit model

Categories	Variables	Environmental accounting		Environmental R&D	
		Coefficients	Z-Value	Coefficients	Z-Value
	EA_i			1.575***	5.88
Policy stringency	P_i	0.162	1.56	0.215*	1.75
	IF_i	0.016**	2.39	0.00234	0.37
Policy instruments	TS_i	−0.044	−0.36	0.174	1.23
	PS_i	0.178	1.19	−0.117	−0.66
	IT_i	−0.133	−1.03	0.257	1.55
	PT_i	0.339***	2.72	−0.215	−1.38
	TA_i	0.211**	2.32	0.078	0.70
Firm/facility characteristic	$Employee_i$	0.000207***	2.84	0.0000767	1.15
	SG_i	−0.011	−0.13	0.101	0.96
	BF_i	0.111	1.03	−0.137	−1.05
	MF_i	0.162*	1.79	0.048	−0.45
Market characteristic	MC_i	0.123	1.32	−0.088	−0.80
Stakeholders	$Listed_i$	0.256**	2.34	−0.107	−0.84
	GM_i	−0.041	−0.46	−0.012	−0.11
Country dummies	Germany	1.36***	9.29	−1.196***	−6.37
	Hungary	−0.674***	−3.64	−0.0000948	−0.00
	Japan	−0.598***	−3.49	0.688***	4.18
	Norway	0.007	0.03	0.291	1.32
	France	−0.014	−0.07	0.029	0.13
	Canada	−0.215	−1.23	−0.066	−0.30
Sector dummies	Textiles	0.033	0.13	0.105	0.35
	Wood	0.082	0.36	0.307	1.11
	Pulp	−0.171	−0.85	0.085	0.32
	Chemical	0.138	0.82	0.15	0.71
	Other non-metallic mineral	0.178	0.76	0.513*	1.89
	Basic Metals	0.075	0.45	0.269	1.28
	Machinery	0.054	0.32	0.206	0.97
	Transport equipment	0.011	0.05	0.189	0.75
	Recycling	−0.157	−0.43	0.228	0.54
	Constant	−2.202***	−8.13	−2.226***	−7.62
Management practices	EMS_i	0.787***	8.11		
	QM_i	0.183*	1.73		
	SM_i	0.137	1.55		
	FCA_i	0.257***	2.69		
	MAS_i	0.212**	1.98		
	PCS_i	0.024	0.23		
	IRP_i	0.074	0.67		

Note: ***, ** and * indicate that the coefficient is statistically significant from 0 at the 1%, 5% and 10% level respectively.

an EMS and a quality management system in place are more likely to adopt an environmental accounting system. In addition, facilities with advanced accounting practices are more likely to adopt an environmental accounting system. The coefficients of the dummy variables for full-cost accounting and management accounting systems are positive and statistically significant at the 1 per cent level and 5 per cent level, respectively.

Next, we examine the estimation results of environmental R&D equation (4.2). The results are presented in the right-hand columns in Table 4.4. As expected, it is found that the environmental accounting system stimulates environmental R&D. The coefficient of EA_i is positive and statistically significant at the 1 per cent level. Thus, our hypothesis that an environmental accounting system promotes environmental R&D is confirmed.

Public policy also plays a role; however, much less so than in the single-equation Tobit model. The coefficient of P_i is positive and statistically significant at 10 per cent level. Thus, a facility which reports facing a very stringent environmental policy is more likely to conduct environmental R&D. On the other hand, we do not find any significant effects for inspection frequency or the reported presence of different policy instruments. None of the coefficients of the policy instruments are significantly different from 0 at the 10 per cent level. Thus, the choice of policy instruments does not have direct effects on environmental R&D.

However, we have to be careful in interpreting these results. The adoption of an environmental accounting system appears to clearly depend on the type of instruments applied. Specifically, the presence of a pollution tax promotes the adoption of environmental accounting system, but technology-based standards do not. This result suggests that facilities are more likely to adopt an environmental accounting system when they face flexible policy instruments. Moreover, the estimation results show that environmental R&D is more likely to be undertaken when facilities have an environmental accounting system in place. There is, therefore, an indirect effect of instrument choices on environmental R&D through environmental accounting.

And finally, we find that liquidity constraints (BP_i) do not affect the incentive to invest in environmental R&D, nor the adoption of the environmental accounting. Furthermore, our findings suggest that the imposition of an environmental tax does not discourage investment in environmental R&D, even if such a measure is more likely to have adverse effects on liquidity (unless the revenue generated is recycled to the affected firms by some other means).

In summary, there is considerable support for the hypothesis that policy stringency induces innovation, at least insofar as it is reflected in investment in environmental research and development. There is also limited support for the hypothesis that more flexible instruments encourage innovation. Our results show that even though the use of flexible environmental policy instruments do not appear to have a direct role in inducing environmental R&D, they do so indirectly through their effect on the adoption of environmental accounting systems. Flexible regulation stimulates environmental R&D, albeit indirectly. And finally, there is indirect evidence that the policy framework can affect the efforts undertaken by facilities to identify commercial and environmental synergies.

V. CONCLUSION

Drawing upon data from manufacturing facilities in seven OECD countries, this study has examined the determinants of investments in environment-related research and development. In particular, elements of the three versions of the Porter Hypothesis (weak, narrow and strong) set out by Jaffe and Palmer (1997) have been tested. First, we investigated the issue by examining the determinants of environment-related research and development expenditures. Second, due to possible measurement error and problems of endogeneity between management and technological initiatives, the estimation was undertaken using a bivariate probit model with environmental accounting and environmental research and development as the dependent variables.

We found strong evidence to support the claim that public policy can induce investment in environmental research and development. In addition, there is limited evidence to support the claim that the use of flexible policy instruments is more likely to induce such investments. While the direct effect of the use of flexible policy instruments on environmental research and development is not significant, it is found that their application can be an important factor to promote the adoption of an environmental accounting system, which in turn induces investment in environment-related research and development. Thus, from the view point of policy instruments, flexibility of the regulation is important. This conclusion is further supported to the extent that facilities which invest in environment-related research and development are thought to be more likely to identify innovations which result in environmental–commercial synergies.

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NOTES

1. In other cases, managers may decide to forsake financial benefits if social aspects of their utility function are sufficiently important. However, such an argument would, of course, require a careful assessment of the potential financial long-run financial returns from improved environmental performance.
2. On the contrary, Boyd (1998b) conducted case studies on pollution prevention and found that rigidity of environmental regulations rather than organizational weaknesses are the reasons for unrealized pollution prevention investment.
3. Arimura et al. (2005) also found the larger firms are more likely to be engaged in environmental R&D.
4. Arimura et al. (2005) provides a basic review of the descriptive statistics of the Japanese R&D survey with focus on R&D activities for environmental purposes.
5. Adoption of an EMS may also potentially be endogenous. However, firms with an environmental accounting system in place are likely to already have an EMS since environmental accounting is a relatively advanced environmental management practice. Moreover, the presence of an EMS does not to seem to have a strong direct influence on decisions on environmental R&D, while an environmental accounting system does.

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APPENDIX 4A

Table 4A.1 List of variables

Categories	Variables	Explanation
Decision variables	ERD_i	Environmental R&D
	EA_i	Adoption of environmental accounting system
Policy stringency	P_i	Stringent env. policy
	IF_i	Inspection frequency
Policy instruments	TS_i	Dummy for technology-based standards
	PS_i	Dummy for performance-based standards
	IT_i	Dummy for input taxes (including energy)
	PT_i	Dummy for emission or effluent taxes
	TA_i	Dummy for technical assistance
Firm/facility characteristics	$Employee_i$	The number of employees
	SG_i	Dummy for sales increase
	BF_i	Dummy for bad performance
	MF_i	Dummy for multi-facilities
Market stakeholders	MC_i	Dummy for oligopoly
	$Listed_i$	Dummy for listed firms
	GM_i	Dummy for global market
	EMS_i	Dummy for EMS
Management practices	QM_i	Dummy for quality management
	SM_i	Dummy for safety management
	FCA_i	Dummy for full-cost accounting
	MAS_i	Dummy for management accounting system
	PCS_i	Dummy for process control system
	IRP_i	Dummy for inventory requirement planning

APPENDIX 4B

Table 4B.1 Descriptive statistics for the Tobit model

Categories	Variable	Mean	Std.
Environmental R&D expenditures	ERD_Exp_i	58.80	2260.7
EMS	EMS_i	0.416	0.493
Env. accounting	EA_i	0.394	0.489
Policy stringency	P_i	0.209	0.407
	IF_i	4.467	7.530
Policy instruments	TS_i	0.766	0.424
	PS_i	0.862	0.345
	IT_i	0.789	0.408
	PT_i	0.757	0.429
	TA_i	0.566	0.496
Firm/facility characteristic	$Employee_i$	400.0	1136.2
	SG_i	0.365	0.481
	BF_i	0.182	0.386
	MF_i	0.498	0.500
Market characteristic	MC_i	0.256	0.437
Stakeholders	$Listed_i$	0.198	0.399
	GM_i	0.437	0.496
Country dummies	USA	0.121	0.326
	Germany	0.315	0.465
	Hungary	0.124	0.330
	Japan	0.256	0.437
	Norway	0.050	0.218
	France	0.061	0.239
	Canada	0.073	0.261
Sector dummies	Food	0.100	0.300
	Textiles	0.046	0.210
	Wood	0.045	0.207
	Pulp	0.085	0.279
	Chemicals	0.170	0.376
	Other non-metallic mineral	0.043	0.203
	Basic metals	0.197	0.398
	Machinery	0.234	0.424
	Transport equipment	0.063	0.243
	Recycling	0.018	0.132

APPENDIX 4C

Table 4C.1 Descriptive statistics for the bivariate probit model

Categories	Variables	Mean	Standard deviation
Environmental R&D	ERD_i	0.090	0.286
Env. accounting	EA_i	0.387	0.487
Policy stringency	P_i	0.207	0.405
	IF_i	4.616	7.793
Policy instruments	TS_i	0.763	0.426
	PS_i	0.863	0.344
	IT_i	0.789	0.408
	PT_i	0.760	0.427
	TA_i	0.563	0.496
Firm/facility characteristic	$Employee_i$	401.3	931.4
	SG_i	0.364	0.481
	BF_i	0.185	0.388
	MF_i	0.510	0.500
Market characteristic	MC_i	0.258	0.438
Stakeholders	$Listed_i$	0.426	0.495
	GM_i	0.204	0.403
Management practices	EMS_i	0.422	0.494
	QM_i	0.774	0.418
	SM_i	0.583	0.493
	FCA_i	0.458	0.498
	MAS_i	0.614	0.487
	PCS_i	0.550	0.498
	IRP_i	0.612	0.487
Country dummies	USA	0.129	0.336
	Germany	0.295	0.456
	Hungary	0.122	0.327
	Japan	0.266	0.442
	Norway	0.052	0.223
	France	0.058	0.233
	Canada	0.078	0.268
Sector dummies	Food	0.098	0.297
	Textiles	0.048	0.214
	Wood	0.048	0.214
	Pulp	0.080	0.271
	Chemicals	0.173	0.379
	Other non-metallic mineral	0.042	0.201
	Basic metals	0.195	0.397
	Machinery	0.230	0.421
	Transport equipment	0.068	0.252
	Recycling	0.018	0.133

5. End-of-pipe or cleaner production? An empirical comparison of environmental innovation decisions across OECD countries

Manuel Frondel, Jens Horbach and Klaus Rennings

I. INTRODUCTION

Typically, we distinguish between two different types of environmental investments that mitigate the environmental burden of production: cleaner production and end-of-pipe technologies. Cleaner production reduces resource use and/or pollution at source by using cleaner inputs and production methods directly within the production process, whereas end-of-pipe technologies curb pollution emissions by implementing add-on measures. Thus, cleaner production technologies are frequently seen as being superior to end-of-pipe technologies for both environmental and economic reasons.

Investment in cleaner production technologies, however, is often hampered by barriers such as additional requirements for coordination and a lack of organizational support within firms. In addition to substantial investment costs in new technologies, additional obstacles arise due to the nature of the environmental problem and the type of regulations involved. Command-and-control (CaC) regulations, for instance, frequently entail technology standards that can only be met through end-of-pipe abatement measures. With respect to the diffusion of cleaner production, the question arises as to which one of several alternative policy approaches is to be preferred: technology-based standards, voluntary measures, or economic instruments, which leave decisions about the appropriate abatement technology up to the firm?

There has been exceptionally little empirical analysis directed at the diffusion of specific types of environmental technologies, principally because of the paucity of available data (Brunnermeier and Cohen 2003; Jaffe et al. 2002). In particular, it is still unclear to what extent and why firms may shift from end-of-pipe solutions to cleaner production. Firstly, do internal factors, such as the existence of environmental management systems (EMSs), support the decision to adopt cleaner production? Secondly, are innovation decisions driven by external factors, such as environmental reglations and pressure from suppliers, customers or other stakeholders?

This chapter empirically analyses facilities' discrete choice between different environmental innovation types. On the basis of the OECD database discussed in Chapter 1, we attempt to identify the determinants of end-of-pipe and cleaner production technologies by using different discrete choice models. The database allows us to address the influence of a variety of correlates, such as environmental policy instruments, market forces, the impact of pressure groups and (environmental) management tools on firms' environmental innovation behaviour.

Given the potential relative advantages of cleaner production technologies, it seems natural that policy makers are primarily interested in identifying factors that affect firms' choice among various types of environmental innovations. Furthermore, it appears particularly desirable from the perspective of environmental policy to identify incentives that can be influenced by policy measures, such as technology-based standards, flexible economic instruments, public procurement, voluntary measures and technology support programmes, and to assess the role of other determinants, such as consumer preferences and firm-specific factors.

In the subsequent section, we commence with the description of environmental innovation types and how these types are addressed in our analysis. Section III reviews the literature on trends and determinants pertaining to the shift from end-of-pipe to cleaner production. Section IV provides a descriptive summary of our data set. In section V, we analyse the decision between end-of-pipe and cleaner production technologies using discrete choice models. In section VI, country-specific differences of the choice among various abatement options are analysed. The final section provides a summary and conclusions.

II. TYPES OF ENVIRONMENTAL INNOVATIONS

The OECD (1997) *Guidelines for Collecting and Interpreting Technological Innovation Data* distinguish between technical and organizational innovations, with technical innovations being divided into product and process innovations (for an illustration of theses distinctions, see Figure 5.1):

- process innovations enable the production of a given amount of output (goods, services) with less input;

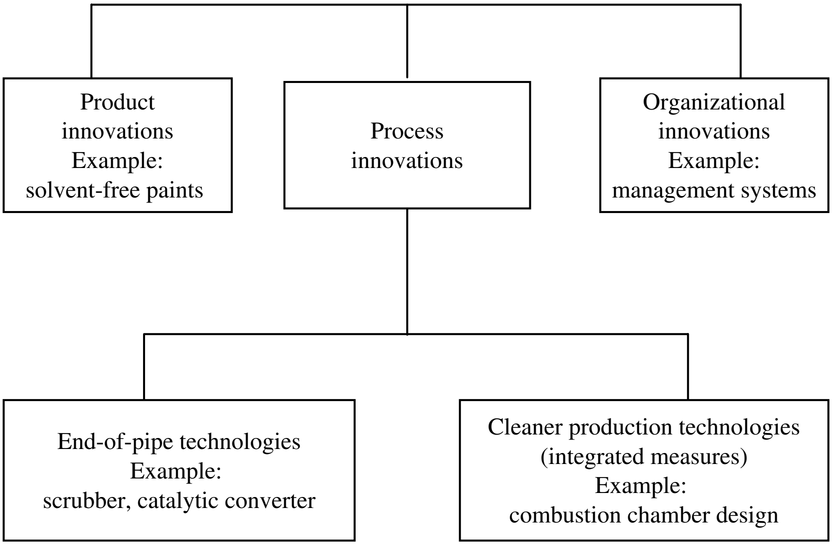


Figure 5.1 Types of environmental innovations

- product innovations encompass the improvement of goods and services or the development of new goods; and
- organizational innovations include new forms of management, such as total quality management.

This distinction is in line with the technical guidelines of the Society of German Engineers (VDI) which sets forth industrial environmental protection measures and their respective costs (VDI 2001). Process-related measures are commonly subdivided into end-of-pipe technologies and integrated technologies (hereinafter: cleaner production technologies). According to the VDI (2001) end-of-pipe technologies do not make up an essential part of the production process, but are add-on measures so as to comply with environmental regulation. Incineration plants (waste disposal), wastewater treatment plants (water protection), sound absorbers (noise abatement), and exhaust-gas cleaning equipment (air quality control) are typical examples of end-of-pipe technologies. In contrast, cleaner production technologies are seen as directly reducing environmentally harmful impacts through changes within the production process. The recirculation of materials, the use of environmentally friendly materials (for example, replacing organic solvents by water), and the modification of the combustion chamber design (process-integrated systems) are examples of cleaner production technologies.

Typically, end-of-pipe technologies, such as filters utilized for desulphurization, are designed to diminish harmful substances that occur as by-products of production. In contrast, cleaner production measures generally lead to reductions of by-products as well as energy and resource inputs. Finally, organizational measures include the reorganization of processes and responsibilities within the firm with the objective of reducing environmental impacts. Environmental management systems (EMS) are typical examples of organizational measures. Organizational innovations contribute to the firms' technological opportunities and can be supporting factors for technological innovations.

Frequently, firms hope that innovations will offset the burden and cost induced by environmental regulation or, at least, that they will help them to achieve environmental policy goals, without incurring severe negative economic consequences. Reduced costs, increased competitiveness, the creation of new markets for environmentally desirable products and processes, positive employment effects, and so on, are seen as potential benefits of an innovation-friendly environmental policy. Yet, these benefits can be realized more easily with cleaner production technologies than with end-of-pipe measures, since end-of-pipe technologies fulfil, by definition, primarily environmental protection tasks. (See also Labonne and Johnstone 2006, which describes Changes in Production Processes (CPP) as the realization of economies of scope between production and abatement.)

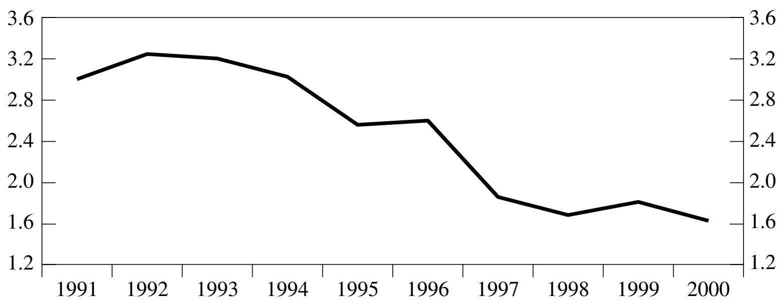
Thus, cleaner production technologies are frequently more advantageous than end-of-pipe technologies for both environmental and economic reasons. But technology choices are often influenced by the specific environmental problem and may be constrained by technological opportunities and the regulatory framework stipulating investment in a certain technology standard that can only be reached with end-of-pipe measures. Apart from the flexibility of regulation, the choice between these two technology options also hinges on the evaluation of the option that is more cost-effective when meeting the required standards.

In short, the complete replacement of end-of-pipe technologies by cleaner production measures is certainly not possible (nor desirable). In practise, there will always be a mix of end-of-pipe and cleaner production technologies that depends on the underlying environmental targets, technology options and related costs. Nevertheless, there is wide agreement on the following three findings: firstly, in the past environmental regulations encouraged the use of end-of-pipe strategies rather than cleaner production technologies; secondly, these technologies are still dominant in OECD countries; and thirdly, shifts to cleaner production would be environmentally and economically beneficial (Rennings et al. 2004a, 2004b).

III. TRENDS AND DETERMINANTS OF FACILITIES' ENVIRONMENTAL TECHNOLOGY CHOICE

Investments in cleaner production technologies cannot be separated all that easily from other, non-environmental technologies (Sprenger 2004). Although international statistical offices, such as Eurostat (OECD and Eurostat 1999), agreed to add cleaner production to the definition of environmental protection activities, international statistics on the use of cleaner production technologies are still rare. On the other hand, data from some national statistical sources indicate that investments in end-of-pipe technologies decreased during the 1990s (for Germany, see Figure 5.2). This observation raises the question as to whether this fact might be explained by the shift of investments to cleaner production technologies. For the USA, such a shift has been observed (Johnstone 2005): from 1988 to 1994, changes in production processes as percent of total pollution abatement costs increased from 27 per cent to 48 per cent (media air) and from 17 per cent to 30 per cent (media water).

Unfortunately, the literature on environmental innovation cannot provide a satisfactory answer to the reasons behind this choice because it draws heavily upon insights of general empirical innovation research, which distinguishes neither between environmental and non-environmental innovations nor between end-of-pipe and cleaner production technologies. In the remaining part of this section, we will review the innovation literature with a focus on the general determinants of innovation decisions, and the implications that they have for the choice of environmental abatement technologies.



Source: Becker and Grundmann (2002).

Figure 5.2 Investments (in bn EUR) in end-of-pipe technologies in German industry in the 1990s

The general innovation literature has been very much concerned with whether technological innovation is triggered by supply-push or demand-pull factors, or by both sets of factors. Often, these factors are also called technology-push and market-pull factors, respectively, with market-pull factors emphasizing the role of consumers', firms' and the government's demand as determinants of environmental innovation (Hemmelskamp 1997). While corporate image and preferences for environmentally friendly products are typical examples of market-pull factors, technology-push factors include subsidies that promote research and development (R&D).

Empirical evidence indicates that both market-pull and technology-push factors are relevant for spurring technological progress and innovation (Pavitt 1984). This also seems to be plausible for the choice among environmental abatement technologies, with market-pull factors expected to be more important for cleaner products than for process innovations (since the latter are not visible for the customer). The major technology-push and market-pull factors found in innovation literature are the technological capabilities, the possibility of appropriation, market structure and other factors, that are described in the following sections.

Technological Capabilities

The concept of technological capabilities, conceived by Rosenberg (1974), encompasses the knowledge and know-how of the development of new processes and products. Empirical studies support the hypothesis that technological capabilities are decisive determinants of innovation cost. They are thus important factors for innovation decisions (Cohen 1995) and relevant for both cleaner production and end-of-pipe technologies. Janz et al. (2003) find evidence that private R&D activities are decisive internal push factors for innovation activities, especially for knowledge-intensive sectors. Financial resources and skilled employees (Czarnitzki 2002), R&D activities, especially activities dedicated to environmental issues, and the support of organizational structures such as management systems, in particular EMSs, also represent important internal capabilities for successful innovation activities. Empirical evidence of the positive impact of EMSs on environmental innovation is found by Rennings et al. (2003) and Rehfeld et al. (2004), while Frondel et al. (2004a) do not find any significant influence.

Possibility of Appropriation

Research investment differs from physical investment, because it is difficult to exclude third parties from the assets produced by the research process. As noted in the classic contribution by Arrow (1962), the creator of these assets will typically fail to appropriate most or even all of the social returns it generates. Much of the social returns will accrue as spillovers to competing firms and consumers. The appropriation problem is likely to lead to significant underinvestment in R&D by private firms (Jaffe et al. 2002). Innovation incentives may increase if the private innovator can appropriate the expected innovation rents. The creation of a temporary monopoly through patents, the implementation of market barriers to complicate and hamper imitation, or keeping the innovation secret are instruments and strategies that can be used to ensure appropriation. Yet, the appropriation problem seems to be of minor importance for environmental innovations, since the expected rents are rather low due to the public good character of most environmental goods and services, due to imperfect internalization of external costs.

Market Structure

As noted above, one of the major innovation incentives is the expectation of innovation rents, even if these rents are temporary (Cohen 1995). In addition to R&D investment profits, strategic advantages over rivals are also motivating forces for innovations (Carraro 2000). Innovation rents are commonly expected to be higher in oligopolistic regimes than in highly competitive markets. Schumpeter (1942) argues that firms with large market shares are superior with regard to innovations due to potential economies of scale for inventive activities. There is also empirical evidence that highly concentrated industries are more innovative than others (Mansfield 1968; Scherer 1967). Yet, once monopolistic rents are secured, the pressure to innovate may decrease. New products and processes are more frequently developed in deregulated markets than in regulated markets (Beise and Rennings 2003). Thus, a few empirical studies also find support for the hypothesis that market concentration has a negative effect on innovations (Geroski 1990; Williamson 1965). Regarding the technology choice between end-of-pipe and cleaner production, it can be expected that firms in protected markets are more likely to opt for end-of-pipe technologies. They can concentrate on environmental protection functions since they experience less competitive pressure simultaneously to improve their resource efficiency.

Miscellaneous Factors, such as Market Demand, Sector-Specific Differences and Firm Size

Both actual and expected market demand crucially affect firms' decisions on R&D investments, especially concerning product innovations (Harabi

1997). Of course, this also holds true for cleaner production investments and, in particular, environmental product innovations. Furthermore, due to specific market situations and technology options the 'modes of innovative search' and the technology choice between end-of-pipe and cleaner production measures differ from sector to sector (Dosi 1988). Innovation processes in the pharmaceutical industry, for example, appear to be rather complex, particularly in comparison to the textile industry, where innovations frequently consist in changes of textile designs. Finally, the complexity of innovations seems to determine the role that the firm's size plays for innovation behaviour. Empirical findings are controversial, though. While complex innovations (most notably process innovations) can be easily accomplished by large firms, less complex innovations (commonly product innovations) frequently originate from small firms due to their higher degree of flexibility (Pavitt 1984). The general existence of economies of scale for innovation activities has not yet been empirically confirmed.

Beyond such technology-push and market-pull factors, regulations are often considered to be an important driving force for environmental innovation. This is at least partially due to the public-goods character of environmental innovation (Rennings 2000), which leads to underinvestment in environmentally related R&D. It is argued that market forces alone would provide insufficient innovation incentives and that consumers' willingness to pay for environmental improvements would be too low. The Porter Hypothesis underscores the view that regulations can trigger environmental innovations and postulates that in a non-optimizing world strict environmental policy may spur 'innovation offsets'; that is, environmental innovations can offset the cost induced by regulations and create new markets for environmentally desirable products and processes. In a series of case studies, Porter and van der Linde (1995) find anecdotal evidence for their hypothesis.

The Porter Hypothesis has been received with scepticism, however (Jaffe and Palmer 1996). While it is widely agreed that potentials for cost savings and improved efficiency may exist in imperfect markets, it is frequently argued that these potentials are rather limited (Ulph 1996). Nevertheless, the Porter Hypothesis might be valid for both of our technology options due to the secondary benefits of an innovation-friendly environmental policy: end-of-pipe technologies might increase, for instance, the competitiveness of an industry that is the forerunner of an international trend. If a country imposes a specific regulation on an industry that requires end-of-pipe investments, firms might have gained a competitive 'first-mover' advantage in the long run once other countries adapt the same regulation. Strict environmental regulations may also improve the competitiveness of firms in the long run by stimulating resource- and cost-efficient, cleaner production measures. Unless firms were myopic prior to the introduction of the regulation, the savings will not offset total abatement costs, but there may still be significant offsets.

Empirical evidence on this issue is rare due to a lack of technology-specific firm data. By analysing the effects of a German environmental investment programme, Horbach et al. (1995) show that in some cases process-integrated measures, as opposed to end-of-pipe technologies, lead to significant cost savings. The same results are obtained in a series of cases studies carried out by Hitchens et al. (2003) for European SMEs. Furthermore, Walz (1999) shows that the introduction of new, integrated technologies in order to curb CO_2 emissions may lead to an increase in total factor productivity. Finally, industry surveys conducted by Pfeiffer and Rennings (2001), Rennings and Zwick (2002) and Rennings et al. (2003) confirm that environmental innovations have a small but nevertheless beneficial economic impact on sales and employment. It remains unclear whether such a small impact induces firms to shift their investments from end-of-pipe to cleaner production technologies.

Market-based instruments have been regarded as superior in the early environmental innovation literature (Downing and White 1986; Milliman and Prince 1989). This characterization has been confirmed for situations of perfect competition and information. Yet, under conditions of imperfect competition, results originating from general equilibrium models of endogenous growth and game theory models suggest that regulation standards may be a more appropriate method for stimulating innovation, particularly when firms gain 'strategic advantages' from innovation; see Carraro (2000) and Montero (2002). Furthermore, when the endogeneity of technological progress is taken into account, as in evolutionary economics and the new institutional and growth theory,[1] none of the policy instruments is generally preferable. According to Fischer et al. (2003), the welfare gains from the implementation of different environmental policy instruments critically depend on the circumstances involved. Frondel et al. (2004a) find that general policy stringency is more important than the choice of single policy instruments.

IV. THE DATA SET AND DESCRIPTIVE RESULTS

In our analysis of different abatement technologies, we use a facility and firm-level data set collected as part of a recent OECD project on environmental policy tools and their impact on firm management practices in manufacturing. (For more details see Chapter 1, as well as the description of the variables used in our study and provided in Appendix 5A.)

Table 5.1 Distribution of abatement technology types in our sample facilities in 2003

Abatement technologies	Number of facilities	%
Cleaner production measures	2380	76.8
End-of-pipe technologies	720	23.2
Total	3100	100

Table 5.2 Distribution of product and process innovations in our sample facilities

Types of environmental innovation	Number of facilities	%
Product innovations	486	15.6
Process innovations	2632	84.4
Total	3118	100

Table 5.1 reports that 3100 of our sample facilities, approximately 74 per cent, took significant technical measures to reduce the environmental impacts associated with their activities. Out of these facilities, 76.8 per cent reported that they had primarily done so through changes in their production technologies, and only a minority of 23.2 per cent implemented end-of-pipe technologies. This is a surprising result, since there is a widespread assumption that end-of-pipe technologies still dominate investment decisions in firms. Recent surveys, though, indicate that cleaner production investment has almost caught up – see the German survey by Cleff and Rennings (1999) – or even exceeded the share of end-of-pipe investment – see the survey by Rennings and Zwick (2002) for the European context.

Regarding the introduction of product or process innovations, the respondents of our sample firms indicated which of these innovation types they use predominantly. Not surprisingly, most facilities report that they took more significant measures in the area of production processes than in product design (see Table 5.2).

There are, however, significant differences among the OECD countries. Most notably, Germany displays the lowest percentage of cleaner production technologies among the seven OECD countries (see Figure 5.3).

The share of cleaner production technologies ranges from 57.5 per cent in Germany to 86.5 per cent in Japan (for more details on the German data, see Frondel et al. 2004b). The reason for this result for Germany appears to be attributable to the fact that CaC has heavily favoured the use of end-of-pipe technologies in Germany in the past (Hauff und Solbach 1999).

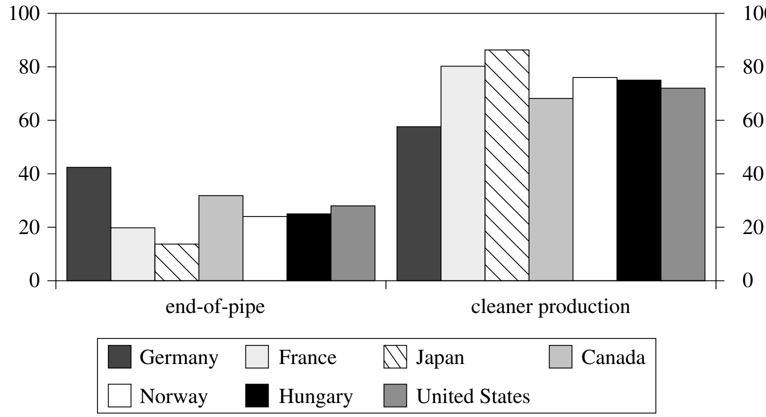


Figure 5.3 Choice of environmental technologies (%) in seven OECD countries

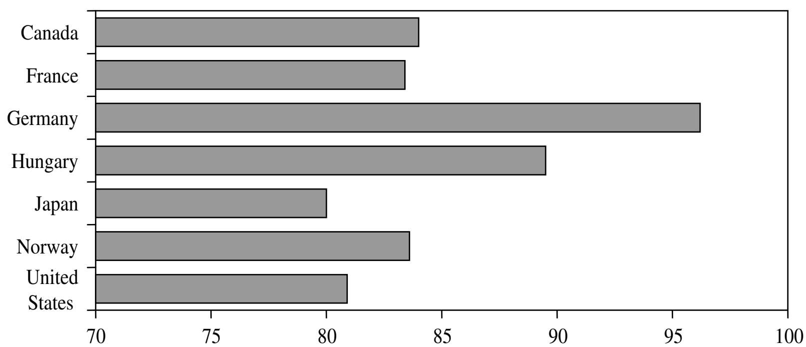


Figure 5.4 Incidence of measures undertaken (% production rather than product)

However, recent empirical results point to a growing importance of cleaner technologies in Germany (Horbach 2003a, 2003b).

While a large majority of our sample facilities report that the established measures to reduce environmental impacts target production processes rather than product design characteristics, Germany and Hungary exhibit the lowest proportion of facilities stating that they implemented product measures (see Figure 5.4). These results are in line with findings of recent surveys in Germany (for example, Rehfeld et al. 2004) and Europe more generally (Rennings and Zwick 2002). These surveys confirm the general view that the rate and direction of environmentally benign technological progress differ according to the type of innovation. While pollution problems have been countered quite successfully through the use of cleaner processes at the production site, product-integrated environmental innovations still suffer from poor market incentives (Rennings et al. 2004b). The crucial problem still seems to be that environmental innovations are not scaled up from niche markets to mass markets (take-off phase).

There are considerable differences among sectors. Whereas product innovations are important for the publishing and printing sector (share of 23 per cent, product rather than production) and the manufacture of electrical machinery and apparatus (21 per cent), they seem to be of minor importance for the manufacture of basic metals (13 per cent) or medical, precision optical instruments, watches and clocks (12 per cent).

V. DETERMINANTS OF TECHNOLOGY CHOICE: END-OF-PIPE VS CLEANER PRODUCTION

In a first step, we investigate the incentives of firms to undertake environmental investment (end-of-pipe or cleaner technologies) versus the no-abatement alternative using an unordered multinomial logit model. On the basis of the OECD firm and facility-level data set summarized in the previous section, we capture a firm's decision on a specific environmental abatement technology by applying the categorical variable choice, which reflects three distinct unordered abatement choices:

1. end-of-pipe technologies;
2. cleaner production technologies; and
3. no new environmental technologies are implemented.

Respondents from our sample firms indicated which of these technology types characterized the nature of their abatement measures most accurately. While a firm may use both types of technology, our categorical variable choice reflects the technology that is predominantly employed by a firm. Clearly, this variable may suffer from the fact that the identification of process-integrated technologies is rather difficult, because they can easily be confused with more general changes to production processes. Another problem results from the fact that firms sometimes cannot easily choose between end-of-pipe technologies or integrated measures – a problem that is based on technological restrictions. Our econometric model addresses this latter issue by using dummies for branches, because some types of technological abatement options may be industry-specific (see the discussion on sector-specific modes of innovative search outlined in section III).

The individual decision of a facility to opt for one of the three abatement alternatives depends on factors that are divided into the following five categories:[2]

1. Motivations: This category captures the goals of environmental protection activities, such as expected corporate *image* improvements, *cost savings* due to the implementation of abatement technologies, potential avoidance of environmental *incidents* and regulatory *compliance*. (*Italic terms* identify the names of the variables used in the tables presenting our estimation results.)
2. Environmental policy instruments: This category comprises respondents' assessment of the importance of environmental policy instruments such as *input bans*, *technology* and *performance standards*, *pollution* and *input taxes* and *subsidies*. Furthermore, we analyse the role of 'soft' instruments such as *information* measures for consumers and buyers and voluntary and negotiated agreements (*voluntary measures*). The stringency of a government's environmental policy may also foster abatement decisions. The variable *policy stringency* describes respondents' perception of the stringency of environmental regulation.
3. Management tools: Different management practices, such as *health and safety management system*s and *process or job control system*s, may have distinct implications for environmental investment and the choice of abatement technologies. Process control systems, for instance, may help identify energy-saving potentials by controlling the whole production process and thus may serve as an information basis for the design of cleaner technologies. This may also be true for specific environmental management tools, such as *written environmental policies*, *internal environmental audit*s, *environmental accounting* and public environmental *reports*. In many cases, the firms need sufficient information about the environmental impacts at each phase of the production process so as to implement cleaner technologies. Environmental management practices may help to provide this information base.
4. Pressure groups: This category reflects the influence of interest groups – as perceived by the survey respondents – such as industrial associations and labor unions (summarized in the variable *labour*), *internal forces*, such as corporate headquarters and management employees, and environmental (*green*) organization*s*.
5. Facility characteristics: Abatement decisions may be affected by a set of facility-specific covariates that are discussed in the literature review provided in section III. Such covariates are, for instance, facility *size* and *turnover*, measured in terms of number of employees and sales, respectively. Finally, the relevance of environmental *impacts* of any

kind of pollution and a person explicitly responsible for environmental concerns, identified as *officer*, might also be relevant. Furthermore, a specific research and development budget for environmental matters (*R&D*) was used as an indicator for the respective technological capabilities. Quantitative indicators for research and development were not available due to a large number of missing values. The influence of the market structure was captured in the variable *competition* reflecting the number of competitors of the responding firm and in the variable *scope* of the market.

Estimation results for our multinomial logit model are reported in Table 5.3 and indicate a significant, positive correlation of environmental *policy stringency*, *technology standards* and regulatory *compliance* with the introduction of end-of-pipe technologies, but not with cleaner production. The relative importance of these three variables for end-of-pipe technologies might be explained by the fact that CaC is still the dominant environmental policy framework. Cleaner production measures, however, tend to be stimulated by other factors than CaC and have been less encouraged by environmental regulations so far.

Another result suggests that innovations in cleaner production technologies tend to be market-driven and not so much regulation-driven: *cost savings* tend to favour process-integrated measures and not end-of-pipe technologies. This result supports the view that the nature of integrated technologies often leads to energy and/or material savings as examples of cost savings. Furthermore, technological capabilities seem to be more important for cleaner technologies than for end-of-pipe measures. The variable *R&D* is only significant for cleaner technologies.

Not surprisingly, facilities that respond that environmental *incidents* are potentially significant impacts from their practices are more likely introduce both technology types. Among stakeholders the *internal forces*, such as corporate headquarters and management, have statistically significant positive effects on the implementation of environmental technologies, be it end-of-pipe or cleaner production technologies. External forces, such as *labour* unions or environmental or neighbourhood groups (*green orgs*) are only weak or not significant with respect to either decision.

Furthermore, (environmental) management tools appear to be particularly important for the introduction of clean technologies. *Process or job control systems* significantly promote the implementation of integrated technologies. *Internal environmental audits* and the preparation of *environmental reports* are only weak or not significantly important for end-of-pipe measures, but they are for cleaner technologies. These results are plausible since both policy tools may help managers to obtain the information

Table 5.3 Multinomial logit model of available abatement options

	End-of-pipe	Cleaner production		End-of-pipe	Cleaner production
	Environmental policy			Motivations	
Policy stringency	1.38 (1.90)$^{+}$	1.22 (1.27)*	Cost savings	1.22 (1.51)	1.61 (4.41)**
Technology standards	1.47 (2.46)**	1.02 (0.16)	Compliance	1.38 (2.11)*	1.15 (1.11)
Input taxes	0.83 (−0.99)	1.03 (0.18)	Image	0.99 (−0.05)	1.09 (0.75)
Pollution taxes	1.36 (1.66)$^{+}$	1.04 (0.26)	Incidents	1.38 (2.27)*	1.34 (2.49)**
Information	0.85 (−0.93)	0.81 (−1.40)			
Voluntary measures	0.88 (−0.60)	1.04 (0.21)		Facility characteristics	
Subsidies	1.11 (0.59)	1.18 (1.07)	Competition	0.92 (−0.71)	1.02 (0.16)
			Impacts	1.77 (4.33)**	1.41 (2.99)**
			Officer	2.14 (4.91)**	1.62 (4.03)**
			R&D	1.28 (0.95)	1.75 (2.45)**
			Size	1.00 (−0.24)	1.00 (−1.78)$^{+}$
			Turnover	1.07 (0.56)	1.03 (0.29)
	Pressure groups			Country dummies	
Internal forces	1.36 (2.19)*	1.42 (2.99)**	France	0.52 (−2.00)*	1.34 (1.06)
Labour	0.65 (−1.90)$^{+}$	0.87 (−0.73)	Germany	0.28 (−4.72)**	0.22 (−6.53)**
Green orgs	1.03 (0.20)	0.96 (−0.26)	Hungary	1.75 (1.83)$^{+}$	2.34 (3.24)**
			Japan	1.51 (1.51)	4.80 (6.85)**
			Norway	0.92 (−0.27)	1.15 (0.55)
			USA	1.66 (1.63)$^{+}$	2.17 (2.78)*

	Management tools			Industry dummies	
Health and safety system	1.30 (2.08)*	1.44 (3.50)**	Textile	0.81 (−0.72)	0.61 (−1.98)*
Process or job control system	1.14 (0.91)	1.34 (2.41)*	Wood	0.51 (−2.15)*	0.72 (−1.31)
Written environmental policy	1.42 (2.30)*	1.52 (3.29)**	Paper	0.94 (−0.24)	0.93 (−0.33)
			Chemicals	0.79 (−1.03)	0.79 (−1.20)
Internal audits	1.28 (1.66)+	1.60 (3.81)**	Minerals	1.53 (1.28)	1.18 (0.56)
Environmental accounting	2.00 (4.06)**	1.70 (3.47)**	Metals	0.86 (−0.67)	0.95 (−0.29)
Environmental reports	1.27 (1.49)	1.51 (2.98)**	Machines	0.39 (−4.28)**	0.58 (−3.05)**
			Transport	0.45 (−2.73)**	0.59 (−2.20)*
			Other sectors	0.80 (−0.50)	0.87 (−0.35)

Notes:
Number of observations: 3699. χ^2 (82) = 1273.45. Pseudo R^2 = 0.179. The base category is 'no abatement technology'. Z-statistics are given in parentheses; +, * and ** denote significance at the 10%, 5% and 1% level, respectively. Exponentiated coefficients are reported. These exponentiated coefficients represent the relative-risk ratio of a one-unit change in the corresponding variable, where the term 'relative risk' describes the risk of the outcome *j* relative to the base outcome (see also STATA 2005, p. 211).

An important assumption of multinomial logit models is that outcome categories have the property of independence of irrelevant alternatives (IIA). The results of Hausman/McFadden tests have shown that there is no systematic change in the coefficients if we exclude one of the alternatives.

required for the introduction of cleaner technologies. The implementation and operation of cleaner technologies is often more complex than for end-of-pipe-technologies. In contrast, *environmental accounting* and a *written environmental policy* seem to favour the introduction of both types of abatement technologies. One explanation might be that environmental accounting reveals the facilities' problems in this area, which may lead to, first, the documentation of both environmental problems and solutions and, second, to abatement actions, irrespective of the type of technology option adopted.

Our estimation results indicate that high reported potential importance of environmental *impacts* for firms is positively correlated with the realization of environmental investments – hardly a surprising result. The introduction of both types of abatement measures is significantly promoted if at least one employee is explicitly responsible for environmental concerns, indicated by the dummy variable *officer*. Estimation results for the industry dummies, which capture the distinct technological options across industries, confirm our expectation that the implementation of cleaner production and end-of-pipe measures varies across manufacturing branches.

Furthermore, we estimated a binary probit model analysing the choice between cleaner (1) and end-of-pipe (0) technologies, allowing direct comparisons of the effects of different determinants. The results (see Table 5.4) show significant differences of the influence of various policy instruments: Whereas input-oriented instruments like *input bans* or *input taxes* seem to trigger cleaner technologies, end-of-pipe measures are promoted by *technology* or *performance standards* and *pollution taxes*. In fact, it is plausible that an input tax, for example on energy consumption, gives a strong incentive to improve the energy efficiency of the whole production process by introducing cleaner technologies. On the other hand, emission reductions triggered by pollution taxes may also be realized by end-of-pipe measures.

Environmental *impacts* are significantly more important for end-of-pipe technologies. This may be due to the fact that, in many cases, cleaner technologies necessitate a change of the whole production process and are therefore not primarily introduced for environmental reasons. This argumentation is confirmed by the significant and positive effect of *cost savings* as important motivation for cleaner technologies.

The positive sign for *internal audits* is plausible because they help to provide the necessary information for the introduction of cleaner technologies. Whereas it is easy to add a filter at the end of the production process, cleaner technologies have to be integrated in complex production processes so that the information requirements are much higher. Similarly, *R&D* inputs also need to be greater to facilitate the introduction of cleaner

Table 5.4 Probit model of cleaner technologies (1) versus *end-of-pipe (0)*

	Environmental policy		Facility characteristics
Policy stringency	−0.02 (−0.80)	Impacts	−0.04 (−2.44)**
Input bans	0.04 (2.10)*	Officer	−0.04 (−1.63)+
Technology standards	−0.05 (−2.20)*	R&D	0.05 (2.07)*
Performance standards	−0.06 (−2.61)**	Size	−0.00 (−2.62)**
Pollution taxes	−0.05 (−2.04)*	$Size^2$	0.00 (1.20)
Input taxes	0.04 (1.68)+	Turnover	−0.01 (−0.53)
Information	−0.01 (−0.55)		
Voluntary measures	0.03 (1.35)		
Subsidies	0.01 (0.44)		
	Management tools		**Country dummies**
Process or job control system	0.03 (1.59)	France	0.11 (2.87)**
		Germany	−0.09 (−2.36)*
Written environmental policy	0.03 (1.77)+	Hungary	0.03 (0.88)
		Japan	0.16 (4.83)**
Internal audit	0.05 (2.24)*	Norway	0.00 (0.09)
		USA	0.04 (1.27)
	Motivations		**Industry dummies**
Compliance	−0.03 (−1.30)	Textile	−0.06 (−1.35)
Cost savings	0.05 (2.98)**	Wood	0.05 (1.32)
		Paper	−0.01 (−0.34)
		Chemicals	−0.01 (−0.39)
		Minerals	−0.06 (−1.25)
		Metals	0.00 (0.04)
		Machines	0.05 (1.85)+
		Transport	0.03 (0.86)
		Other sectors	0.02 (0.28)

Notes:
Number of observations: 2826. χ^2 (35) = 242.16. Pseudo R^2 = 0.080. Z-statistics are given in parentheses; +, * and ** denote significance at the 10%, 5% and 1% level, respectively. Marginal effects are reported instead of coefficients.

technologies, and this is reflected in the positive and significant influence of this variable.

VI. COUNTRY-SPECIFIC RESULTS

In this section, we empirically analyse the country-specific determinants of the introduction and choice of abatement technologies. Unfortunately, it is impossible to estimate multinomial logit models for these choices for all seven countries because the sample sizes are rather small in four cases. For this reason, we only present estimation results for Germany, Hungary and Japan. Furthermore, we aggregated some of our policy variables. As noted above, an important assumption in the context of multinomial logit models is the independence of irrelevant alternatives (IIA). The results of Hausman-McFadden tests show that there is no systematic change in the estimation results of these three countries if we exclude one of the abatement alternatives.

Generally, country-specific differences may arise from:

- the relative importance of different environmental policy instruments and management tools;
- distinct perceptions of environmental problems; and
- traditional preferences for the choice of abatement technologies in the past, and so on.

Environmental policy has a long tradition in Germany (see Table 5.5), and *policy stringency* still appears to be very important for the introduction of both types of abatement technologies as is documented by the significance of the respective variable. The significantly high relative-risk ratios of *internal forces*, representing the influence of headquarters and management employees, may be a confirmation of the hypothesis that due to the high environmental consciousness of the German population, firms anticipate potential external pressure and voluntarily initiate environmental activities. Other internal factors, such as a person that is explicitly responsible for environmental issues (*officer*) and the firms' assessment of their environmental *impacts*, also appear to be relevant for both decisions. On the other hand, external pressure groups do not seem to play any role for the abatement decisions of German firms.

In Japan (see Table 5.6), environmental policy legislation was also developed early. It is widely regarded to be one of the strictest among highly industrialized countries, particularly concerning air pollution (Hibiki and Arimura 2004). Interestingly, only 3.5 per cent of our Japanese sample firms perceive Japan's environmental policy as very stringent, presumably a reflection of the high environmental awareness of Japanese firms. This might explain why the development of cleaner technologies does not depend significantly on public policy initiatives, but rather on potential environmental *impacts*, the existence of a person explicitly responsible for environmental concerns (*officer*), and several management tools, such as a *process or job control system*.

In Hungary (see Table 5.7), the launch of a fully-developed environmental policy framework can be traced back to the beginning of the 1990s.

Table 5.5 Multinomial logit model of available abatement options: Germany

	End-of-pipe	Cleaner production		End-of-pipe	Cleaner production
	Environmental policy			Motivations	
Policy stringency	1.91 (2.13)*	1.85 (2.17)*	Image	0.86 (−0.53)	0.74 (−1.15)
Regulatory measures	1.24 (0.87)	0.94 (−0.27)	Incidents	1.42 (1.44)	0.92 (−0.36)
Market instruments	1.15 (0.56)	1.03 (0.14)	Cost savings	1.29 (1.03)	1.78 (2.63)**
Information	0.71 (−1.04)	0.52 (−2.05)*			
Voluntary measures	1.07 (0.17)	2.05 (2.12)*			
Subsidies	1.15 (0.46)	0.82 (−0.70)			
	Pressure groups			Facility characteristics	
Internal forces	1.96 (2.67)**	1.64 (2.27)*	Impacts	1.91 (2.48)*	2.07 (3.03)**
Unions	0.65 (−0.79)	1.07 (0.14)	Officer	1.85 (2.11)*	2.15 (3.04)**
Green orgs	1.25 (0.62)	0.98 (−0.07)	R&D	2.07 (0.96)	2.02 (0.96)
			Size	1.00 (1.55)	1.00 (1.65)
			Turnover	1.03 (0.14)	1.29 (1.25)
	Management tools			Industry dummies	
Health and safety system	1.16 (0.63)	1.06 (0.27)	Textile	0.32 (−1.82)	0.48 (−1.28)
Process or job control system	1.31 (1.07)	1.15 (0.65)	Wood	1.65 (0.69)	0.83 (−0.24)
			Paper	0.55 (−1.22)	1.16 (0.33)
Written environmental policy	2.03 (2.45)*	1.05 (0.19)	Chemicals	0.80 (−0.49)	1.26 (0.54)
			Minerals	1.09 (0.13)	0.63 (−0.68)
Internal audits	0.90 (−0.36)	1.22 (0.76)	Metals	0.48 (−1.70)	0.75 (−0.73)

Table 5.5 (continued)

	End-of-pipe	Cleaner production		End-of-pipe	Cleaner production
	Management tools			Industry dummies	
Environmental accounting	2.54 (3.17)**	2.00 (2.87)**	Machines	0.19 (−3.65)**	0.40 (−2.22)*
Environmental reports	1.24 (0.66)	2.02 (2.35)*	Transport	0.13 (−2.68)**	0.28 (−1.98)*
			Recycling	0.54 (−0.62)	1.01 (−0.01)

Notes:
Number of observations: 738. χ^2 (64) = 286.28. Pseudo R^2 = 0.187. The base category is 'no abatement technology'. Z-statistics are given in parentheses; * and ** denote significance at the 5% and 1% level, respectively. Exponentiated coefficients are reported. These exponentiated coefficients represent the relative-risk ratio of a one-unit change in the corresponding variable, where the term 'relative risk' describes the risk of the outcome j relative to the base outcome (see also STATA 2005, p. 211).

An important assumption of multinomial logit models is that outcome categories have the property of independence of irrelevant alternatives (IIA). The results of Hausman/McFadden tests have shown that there is no systematic change in the coefficients if we exclude one of the alternatives.

Table 5.6 Multinomial logit model of available abatement options: Japan

	End-of-pipe	Cleaner production		End-of-pipe	Cleaner production
	Environmental policy			Motivations	
Policy stringency	2.70 (1.17)	2.09 (0.95)	Compliance	1.97 (2.07)*	1.44 (1.55)
Regulatory measures	1.48 (1.03)	1.11 (0.33)	Cost savings	1.19 (0.60)	1.36 (1.43)
Market instruments	1.01 (0.02)	0.76 (−0.98)	Image	1.11 (0.34)	1.14 (0.57)
Information	0.78 (−0.58)	0.86 (−0.43)	Incidents	1.17 (0.49)	1.30 (1.13)
Voluntary measures	1.75 (0.89)	1.24 (0.38)			
Subsidies	1.32 (0.50)	1.32 (0.59)			
	Pressure groups			Facility characteristics	
Internal forces	1.37 (0.89)	1.67 (1.82)$^{+}$	Competition	0.76 (−1.10)	0.88 (−0.75)
Unions	1.27 (0.31)	1.51 (0.61)	Scope	0.63 (−1.30)	0.75 (−1.12)
Green orgs	1.88 (1.73)	1.34 (0.95)	Impacts	2.75 (3.66)**	1.78 (2.70)**
			Officer	2.66 (2.85)**	1.92 (2.71)**
			R&D	1.44 (0.73)	2.00 (1.66)$^{+}$
			Size	1.00 (−2.47)*	1.00 (−3.53)**
			Turnover	1.28 (0.79)	1.06 (0.27)
	Management tools			Industry dummies	
Health and safety system	1.36 (1.26)	1.64 (2.88)**	Textile	2.22 (1.39)	0.70 (−0.86)
Process or job control system	4.20 (2.36)*	3.58 (2.38)*	Wood	0.78 (−0.27)	0.75 (−0.53)
			Paper	2.42 (1.65)$^{+}$	1.18 (0.43)
Written environmental policy	1.38 (0.84)	1.55 (1.58)	Chemicals	2.11 (1.49)	1.08 (0.22)
			Minerals	4.02 (1.72)$^{+}$	1.67 (0.82)

Table 5.6 (continued)

	End-of-pipe	Cleaner production		End-of-pipe	Cleaner production
	Management tools			Industry dummies	
Internal audits	1.11 (0.31)	1.56 (1.78)$^{+}$	Metals	1.35 (0.65)	1.02 (0.05)
Environmental accounting	4.95 (2.32)*	3.18 (1.84)$^{+}$	Machines	0.52 (−1.41)	0.62 (−1.62)
Environmental reports	0.84 (−0.44)	0.95 (−0.17)	Transport	0.80 (−0.36)	0.73 (−0.74)
			Other sectors	0.53 (−0.54)	0.76 (−0.46)

Notes:
Number of observations: 1306. χ^2 (70) = 294.04. Pseudo R^2 = 0.146. The base category is 'no abatement technology'. Z-statistics are given in parentheses; $^{+}$,* and ** denote significance at the 10%, 5% and 1% level, respectively. Exponentiated coefficients are reported. These exponentiated coefficients represent the relative-risk ratio of a one-unit change in the corresponding variable, where the term 'relative risk' describes the risk of the outcome *j* relative to the base outcome (see also STATA 2005, p. 211).

An important assumption of multinomial logit models is that outcome categories have the property of independence of irrelevant alternatives (IIA). The results of Hausman/McFadden tests have shown that there is no systematic change in the coefficients if we exclude one of the alternatives.

Table 5.7 Multinomial logit model of available abatement options: Hungary

	End-of-pipe	Cleaner production		End-of-pipe	Cleaner production
	Environmental policy			Motivations	
Policy stringency	3.81 (2.59)**	2.34 (1.78)+	Compliance	1.57 (0.63)	1.01 (0.01)
Regulatory measures	2.21 (1.66)+	1.41 (0.86)	Cost savings	0.72 (−0.75)	0.97 (−0.08)
Market instruments	1.03 (0.05)	0.99 (−0.03)	Image	1.04 (0.08)	1.68 (1.21)
Information	1.04 (0.07)	1.08 (0.16)	Incidents	0.46 (−1.35)	0.75 (−0.59)
Voluntary measures	0.53 (−1.26)	0.67 (−0.95)			
Subsidies	1.75 (1.14)	1.54 (1.00)			
	Pressure groups			Facility characteristics	
Internal forces	1.12 (0.25)	1.35 (0.78)	Competition	0.60 (−1.18)	0.81 (−0.58)
Unions	3.95 (1.85)+	2.67 (1.44)	Scope	1.74 (1.35)	1.78 (1.62)
Green orgs	0.39 (−2.07)*	0.43 (−2.08)*	Impacts	1.08 (0.14)	0.58 (−1.12)
			Officer	2.36 (1.76)+	2.11 (1.87)+
			Size	1.00 (1.32)	1.00 (0.18)
			Turnover	1.25 (0.56)	1.14 (0.36)
	Management tools			Industry dummies	
Health and safety system	0.99 (−0.02)	0.70 (−0.79)	Textile	0.23 (−1.78)+	0.11 (−3.07)**
Process or job control system	0.92 (−0.21)	1.03 (0.08)	Wood	0.06 (−2.09)*	0.22 (−1.81)+
			Paper	0.69 (−0.34)	0.32 (−1.20)
Written environmental policy	1.24 (0.44)	1.17 (0.39)	Chemicals	0.17 (−2.04)*	0.13 (−2.62)**
			Minerals	2.88 (0.80)	1.43 (0.28)
Internal audits	1.64 (1.07)	1.56 (1.10)	Metals	0.50 (−0.77)	0.31 (−1.46)

Table 5.7 (continued)

	End-of-pipe	Cleaner production		End-of-pipe	Cleaner production
	Management tools			Industry dummies	
Environmental accounting	3.49 (1.46)	3.27 (1.47)	Machines	0.74 (−0.39)	0.48 (−1.05)
Environmental reports	1.66 (1.13)	2.21 (2.03)*	Transport	0.21 (−1.44)	0.09 (−2.45)*
			Other sectors	0.23 (−1.53)	0.19 (−1.96)*

Notes:
Number of observations: 421. χ^2 (68) = 114.84. Pseudo R^2 = 0.151. The base category is 'no abatement technology'. Z-statistics are given in parentheses; $^+$, * and ** denote significance at the 10%, 5% and 1% level, respectively. Exponentiated coefficients are reported. These exponentiated coefficients represent the relative-risk ratio of a one-unit change in the corresponding variable, where the term 'relative risk' describes the risk of the outcome *j* relative to the base outcome (see also STATA 2005, p. 211).

An important assumption of multinomial logit models is that outcome categories have the property of independence of irrelevant alternatives (IIA). The results of Hausman/McFadden tests have shown that there is no systematic change in the coefficients if we exclude one of the alternatives.

Hence, the development of Hungary's environmental policy is still in progress (Kerekes et al. 2004). Our estimations show that outside interest groups significantly affect the introduction of abatement technologies, whereas there does not seem to be a significant influence of *internal forces*, such as management employees and corporate headquarters. In a country like Hungary, where environmental problems are only beginning to play an important role, the influence of pressure groups may possibly be higher than in countries with a long environmental policy tradition, where the pressure of interest groups has already been transferred to environmental policy. In contrast to the estimation results for the complete sample reported in Table 5.3, in Hungary, environmental accounting systems do not seem to be important for the introduction of environmental abatement technologies. This result may be explained by the fact that only 12.5 per cent of our Hungarian sample firms use an environmental accounting system, whereas 69 per cent of the German sample firms have already implemented such a system. As accounting systems help to detect possibilities for *cost savings*, this fact might explain that this factor is not relevant for the introduction of cleaner technologies in Hungary, which contrasts with the results for Germany as well as the pooled sample including all countries.

VII. SUMMARY AND CONCLUSIONS

This chapter analyses factors that may enhance a firm's propensity to implement cleaner production technologies rather than end-of-pipe technologies. While both of these two fundamental types of abatement measures mitigate the adverse environmental impacts of production, cleaner production technologies are frequently more advantageous than end-of-pipe technologies for both environmental and economic reasons. In fact, environmental innovations are more often closely identified with cleaner production measures than with end-of-pipe technologies, which reduce environmental impacts by using add-on measures without changing the production process.

Nevertheless, it is a widespread assumption that end-of-pipe technologies still dominate investment decisions in firms. There has been little empirical analysis directed to the determinants of the use of specific types of abatement measures – principally because of the paucity of available data. On the basis of a unique facility-level data set based on a recent survey covering seven OECD countries (Canada, France, Germany, Hungary, Japan, Norway and the USA), we find a clear dominance of cleaner production in these countries. Surprisingly, 76.8 per cent of our sample facilities report that they predominantly invest in cleaner production technologies. There are, however, significant differences. Most notably, Germany displays the lowest percentage of cleaner production technologies among these OECD countries (57.5 per cent), while Japan exhibits the highest respective share (86.5 per cent). The explanation appears to be that Germany's command-and-control policy heavily supported end-of-pipe technologies in the past. Recent empirical results, however, point to the growing importance of cleaner technologies in Germany.

Our estimation results, which are based on discrete choice models, indicate that cost savings tend to favour clean production and that technology standards and the stringency of environmental policy are positively correlated with end-of-pipe technologies. These results suggest that the application of end-of-pipe measures depends at least partially on regulatory pressure, whereas cleaner production may be motivated – among other factors – by market forces. Furthermore, we find empirical evidence that organizational innovations improve the technological capabilities of facilities: general management systems and specific environmental management tools, such as process control systems or environmental audits, seem to support the implementation of cleaner production measures, presumably by improving the necessary information basis for the development of such technologies.

There are also significant differences in the influence of various policy instruments: whereas input-oriented instruments like input bans or input taxes seem to trigger cleaner technologies, end-of-pipe measures are promoted by technology or performance standards and pollution taxes.

We thus conclude that improvements towards cleaner production may be achieved through reforms in the environmental policy framework and by developing and disseminating environmental management tools to a larger extent. Furthermore, the introduction of cleaner technologies is supported by R&D investment specifically related to environmental matters. Finally, there are country-specific differences in the determinants of the introduction of abatement technologies that may arise from distinct perceptions of environmental problems. In Hungary, for instance, external pressure groups are more important for the implementation of environmental technologies, whereas internal forces appear to be decisive in Japan and Germany.

We conclude that additional investments in cleaner production may be stimulated by widening the cost gap between the two types of technologies; for instance, by additionally charging for the use of waste and energy. The potential for continuously substituting end-of-pipe technologies with cleaner technologies might be limited, however, since not all regulatory incentives favouring end-of-pipe technologies can be removed. For example, additional filters currently reduce particulate emissions of diesel cars more effectively than the more eco-efficient diesel engines. Thus, a certain amount of end-of-pipe technologies will still be necessary to curb specific emissions which cannot easily be reduced with cleaner production measures.

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NOTES

1. For a comprehensive survey see Aghion and Howitt (1998).
2. All variables are constructed from the answers provided by the survey respondents. This approach is far from unproblematic, since these responses reflect both genuine variations across facilities and individual differences in the perception of the respondents. For descriptive statistics and details on construction, see Appendix 5A.

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APPENDIX 5A

Table 5A.1 Description and descriptive statistics of the data set

Name of variable	Description	Mean	Std. Dev.
Choice	End-of-pipe or integrated (change in processes) technologies (1 end-of-pipe, 2 integrated, 3 no new abatement technology)	–	–
Binary choice	1 Cleaner technologies, 0 End-of-pipe technologies	0.77	0.42
Motivations for environmental activities	*The variables get the value 1 when 'very important' was chosen, and 0 for other categories*		
Compliance	Regulatory compliance	0.64	0.48
Incidents	Prevent or control environmental incidents	0.57	0.50
Image	Corporate profile/image	0.46	0.50
Cost savings	Cost savings	0.43	0.50
Environmental policy instruments			
Policy stringency	Stringency of environmental policy (1 stringent, 0 not or moderately stringent) The following variables get the value 1 when 'very important' was chosen for at least one of the items, and 0 for other categories:	0.17	0.37
Input bans	Input bans	0.23	0.42
Technology standards	Technology-based standards (e.g. abatement equipment)	0.21	0.41
Performance standards	Performance-based standards (e.g. emission levels)	0.31	0.46
Pollution taxes	Emission or effluent taxes or charges	0.24	0.44
Input taxes	Input taxes (including energy)	0.26	0.44
Regulatory measures	Input bans, technology and performance standards	0.43	0.50
Market instruments	Taxes, tradable permits, liability for environmental damages	0.47	0.50
Information	Information measures for consumers and buyers	0.15	0.36

Table 5A.1 (continued)

Name of variable	Description	Mean	Std. Dev.
Voluntary measures	Voluntary or negotiated agreements	0.11	0.31
Subsidies	Subsidies, tax preferences, technical aid programmes	0.18	0.39
Management tools			
Health and safety system	Health and safety management system (1 yes, 0 no)	0.56	0.50
Process or job control system	Process or job control system (1 yes, 0 no)	0.44	0.50
Written environmental policy	Written environmental policy (1 yes, 0 no)	0.58	0.49
Internal audit	Internal environmental audits (1 yes, 0 no)	0.57	0.50
Environmental accounting	Environmental accounting (1 yes, 0 no)	0.30	0.46
Environmental reports	Public environmental report (1 yes, 0 no)	0.25	0.43
Role of interest groups and organizations	*The variables get the value 1 when 'very important' was chosen for at least one of the items, and 0 for other categories*		
Internal forces	Corporate headquarters, management employees, shareholders	0.49	0.50
Customers	Consumers, commercial buyers, suppliers, banks	0.36	0.48
Labour	Industrial associations, labour unions	0.10	0.31
Green orgs	Environmental organizations, neighbourhood groups	0.22	0.41
Facility characteristics			
Competition	More than 10 competitors (1), less or equal 10 competitors (0)	0.38	0.48
Scope	Scope of the market (1 global, 0 local, regional, national)	0.39	0.49
Impacts	Importance of environmental impacts (1 very negative impacts, 0 other)	0.34	0.47
Officer	Existence of a person explicitly responsible for environmental concerns (1 yes, 0 no)	0.70	0.46

Table 5A.1 (continued)

Name of variable	Description	Mean	Std. Dev.
Primary customer	Primary customers of the facility's products (1 households, wholesalers or retailers, 0 other manufacturing firms or facilities within the firm)	0.38	0.49
R&D	Existence of a budget specifically related to environmental matters (1 yes, 0 no)	0.09	0.29
Size	Number of full-time employees in the last three years	332.0	855.9
$Size^2$	Square of the number of full-time employees in the last three years	842681	$1.66*10^7$
Turnover	Change of turnover in the last three years (0 if it decreased or stayed about the same, 1 if it increased)	0.33	0.47

APPENDIX 5B SECTOR-SPECIFIC DIFFERENCES

Sector-specific differences regarding the choice of abatement technologies may be detected when we distinguish between 'environmental-intensive' and 'environmental-extensive' (or environmentally 'friendly') industries. The basic metals and metal products industry is an example of an environmentally intensive sector, as indicated by the high environmental investment cost that is required to avoid negative environmental impacts (for a discussion of such an indicator, see Horbach 2004). The comparison of this sector's estimation results with those for the (electrical) machinery industry, which is rather an environmentally friendly sector, shows that cost savings are relevant for the environmental-intensive firms, but not for firms with low environmental cost, indeed not a surprising result.

Environmental reports, *internal audits* and the facility *size* seem to be particularly relevant for environmentally friendly sectors: firms that are not forced to introduce significant environmental measures for regulatory reasons need to be of sufficient size to bear the associated costs.

Table 5B.1 Multinomial logit model of abatement options: basic metals, metal products (27, 28)

	End-of-pipe	Cleaner production		End-of-pipe	Cleaner production
	Environmental policy			Motivations	
Policy stringency	1.23 (0.55)	0.95 (−0.14)	Image	0.74 (−0.92)	0.92 (−0.27)
Regulatory measures	0.99 (−0.02)	0.82 (−0.67)	Incidents	1.23 (0.68)	1.53 (1.58)
Market instruments	0.80 (−0.69)	0.62 (−1.64)	Cost savings	2.02 (2.28)*	2.62 (3.46)**
Voluntary measures	0.66 (−0.80)	1.27 (0.51)			
Subsidies	1.80 (1.45)	1.40 (0.89)			
	Pressure groups			Facility characteristics	
Internal forces	2.59 (2.81)**	2.79 (3.32)**	Competition	0.76 (−1.02)	0.84 (−0.70)
Green orgs	1.24 (0.54)	1.09 (0.23)	Impacts	2.50 (3.01)**	1.97 (2.46)*
			Officer	1.43 (0.99)	1.35 (0.96)
			Size	1.00 (0.02)	1.00 (−1.94)
			Turnover	1.03 (0.11)	1.24 (0.80)
	Management tools			Country dummies	
Health and safety system	1.40 (1.17)	1.90 (2.54)*	Germany	0.62 (−0.75)	0.40 (−1.59)
Process or job control system	1.64 (1.48)	1.53 (1.37)	France	9.94 (2.51)*	25.40 (3.89)**
Written environmental policy	1.70 (1.52)	2.54 (2.97)**	Hungary	6.91 (2.30)*	9.45 (2.93)**

Table 5B.1 (continued)

	End-of-pipe	Cleaner production		End-of-pipe	Cleaner production
	Management tools			Country dummies	
Internal audits	1.06 (0.16)	1.16 (0.48)	Japan	5.24 (2.36)*	18.88 (4.73)**
Environmental accounting	2.36 (2.13)*	3.02 (2.88)**	Norway	2.93 (1.36)	4.65 (2.22)*
Environmental reports	1.58 (1.14)	1.82 (1.62)	USA	7.16 (2.66)**	8.03 (3.04)**

Notes:
Number of observations: 735. χ^2 (54) = 312.90. Pseudo R^2 = 0.222. The base category is 'no abatement technology'. Z-statistics are given in parentheses; * and ** denote significance at the 5% and 1% level, respectively. Exponentiated coefficients are reported. These exponentiated coefficients represent the relative-risk ratio of a one-unit change in the corresponding variable, where the term 'relative risk' describes the risk of the outcome *j* relative to the base outcome (see also STATA 2005, p. 211).

An important assumption of multinomial logit models is that outcome categories have the property of independence of irrelevant alternatives (IIA). The results of Hausman/McFadden tests have shown that there is no systematic change in the coefficients if we exclude one of the alternatives.

Table 5B.2 Multinomial logit model of abatement options: (electrical) machinery (29), office, accounting and computing machinery, radio, television, communication, medical, precision optical instruments, watches and clocks (29–33)

	End-of-pipe	Cleaner production		End-of-pipe	Cleaner production
	Environmental policy			Motivations	
Policy stringency	0.80 (−0.47)	0.85 (−0.40)	Image	1.01 (0.04)	1.08 (0.33)
Regulatory measures	0.94 (−0.17)	1.16 (0.54)	Incidents	2.25 (2.49)*	1.31 (1.17)
Market instruments	1.68 (1.55)	0.78 (−0.98)	Cost savings	1.61 (1.58)	1.38 (1.42)
Information	0.55 (−1.27)	0.87 (−0.42)			
Voluntary measures	0.89 (−0.22)	0.93 (−0.16)			
Subsidies	0.72 (−0.72)	1.58 (1.31)			
	Pressure groups			Facility characteristics	
Internal forces	1.22 (0.62)	1.81 (2.38)*	Impacts	2.99 (3.25)**	1.49 (1.51)
Unions	1.04 (0.06)	1.22 (0.41)	Officer	2.74 (2.71)**	1.70 (2.15)*
Green orgs	0.79 (−0.59)	0.79 (−0.80)	Size	1.00 (2.40)*	1.00 (2.37)*
			Turnover	1.82 (2.05)*	1.09 (0.39)
	Management tools			Country dummies	
Health and safety system	1.60 (1.55)	1.38 (1.50)	Germany	0.61 (−0.65)	0.07 (−4.94)**
Process or job control system	2.31 (2.35)*	2.31 (3.00)**	France	0.96 (−0.04)	0.70 (−0.60)
			Hungary	19.19 (3.69)**	4.28 (2.49)*

Table 5B.2 (continued)

	End-of-pipe	Cleaner production		End-of-pipe	Cleaner production
	Management tools			Country dummies	
Internal audits	1.04 (0.12)	1.63 (1.99)*	Japan	4.99 (2.19)*	5.52 (3.55)**
Environmental accounting	2.17 (1.81)	3.48 (3.35)**	Norway	3.29 (1.53)	0.67 (−0.74)
Environmental reports	1.36 (0.83)	2.11 (2.54)*	USA	8.38 (2.26)*	2.80 (1.37)

Notes:
Number of observations: 910. χ^2 (54) = 483.08. Pseudo $R^2 = 0.287$. The base category is 'no abatement technology'. Z-statistics are given in parentheses; * and ** denote significance at the 5% and 1% level, respectively. Exponentiated coefficients are reported. These exponentiated coefficients represent the relative-risk ratio of a one-unit change in the corresponding variable, where the term 'relative risk' describes the risk of the outcome *j* relative to the base outcome (see also STATA 2005, p. 211).

An important assumption of multinomial logit models is that outcome categories have the property of independence of irrelevant alternatives (IIA). The results of Hausman/McFadden tests have shown that there is no systematic change in the coefficients if we exclude one of the alternatives.

6. Understanding the relationship between a facility's environmental and financial performance

Nicole Darnall, G. Jason Jolley and Bjarne Ytterhus

I. INTRODUCTION

An understanding of how a company's environmental performance affects its financial prospects, and how the stringency of the environmental policy regime might constrain a company's financial opportunities, are issues of considerable concern to policy makers. Collectively, organizations spend millions of dollars annually when installing mandated pollution-control technology, applying for environmental permits, and monitoring and reporting their environmental impacts (Portney and Stavins 2000). These costs create an incentive for companies to reduce their environmental impacts below minimum reporting thresholds. Doing so also benefits organizations by improving their operational efficiencies. At the same time, regulators can achieve greater environmental improvements without additional monitoring and enforcement. However, questions remain about the extent to which the stringency of the environmental regulatory regime diminishes a company's financial performance.

Other uncertainties relate to whether or not more efficient companies may be the ones that actively reduce their impacts on the natural environment. As such, a company's superior financial outcomes may be mistakenly attributed to its improved environmental performance, when financial performance is related more to the fact that a company is more efficient from the outset. These issues have been ignored by many prior studies (for example, Stanwick and Stanwick 2000; Russo and Fouts 1997; Levy 1995; Hart and Ahuja 1996; Cormier et al. 1993; Arora and Cason 1995). Moreover, previous research has not explored how the stringency of the environmental policy regime affects a company's environmental and financial performance. Perhaps most importantly, the link between a company's environmental and financial performance has not been studied across multiple countries.

In this chapter the link between facilities' environmental and financial performance is examined, taking into account potential endogeneity associated with improved environmental performance. It draws upon OECD data from manufacturing facilities operating in Canada, France, Germany, Hungary, Japan, Norway and the United States, and utilizes simultaneous equation techniques. The results show that the stringency of the environmental policy regime was associated with fewer financial performance opportunities. However, these opportunities were mitigated if the facility took steps to reduce its impacts upon the natural environment. These findings are important because they provide evidence that may encourage additional companies to take a more proactive stance in how they manage their environmental affairs, as well as evidence that the costs of complying with the environmental regulatory system can be lessened or overcome if organizations undertake proactive environmental strategies.

II. DO COMPANIES BENEFIT FINANCIALLY BY IMPROVING THEIR ENVIRONMENTAL PERFORMANCE?

Orthodox economic theory suggests that organizations should invest in environmental activities only to the extent that their marginal benefit of doing so equals their marginal cost. Interpreted more strictly, investment beyond the current regulatory requirements is detrimental to an organization's economic performance and constrains financial opportunities (Friedman 1970; Christiansen and Haveman 1981; Conrad and Morrison 1989; Denison 1979; Jaffe and Palmer 1997; Lave 1973; Norsworthy et al. 1979). This rationale suggests that there is little incentive for an organization to be environmentally proactive, and therefore little reason to examine the relationship between environmental and financial performance.

Despite this traditional wisdom, anecdotal evidence suggests that financial benefits exist for 'green' firms, which has caused many companies to try to portray themselves as being environmentally friendly. For example, 3M reported saving more than US$1 billion between 1975 and 1990 due to implementing a rigorous pollution prevention programme and to reducing its air pollution emissions by approximately 125 000 metric tonnes (McCloskey 1993). Similarly, by 1998 participation in the US Environmental Protection Agency's (EPA's) more than 40 voluntary environmental programmes had attracted a projected 13 000 organizations (Mazurek 1998). Still other firms have voluntarily reduced their emissions significantly over time and reduced their environmental impacts to qualify for eco-labels.

These organizations have not necessarily acted against conventional economic wisdom, because companies that invest in proactive environmental strategies may benefit substantially (for example, Hart and Ahuja 1996; Henderson and Mitchell 1997; Klassen and McLaughlin 1996; Porter and van der Linde 1995). Some benefits relate to regulation itself since achieving regulatory compliance is costly. The regulatory framework therefore creates an incentive for firms to improve their operational efficiencies by reducing their product inputs, waste treatment costs and long-term liabilities (Porter and van der Linde 1995).

Other financial benefits may also accrue from markets (Konar and Cohen 1997; Arora and Cason 1996; Khanna and Damon 1999). Market pressures for environmental consideration have increased as firms and customers have become increasingly aware of the environment. Information about an organization's environmental performance also affects corporate reputation (Arora and Gangopadhyay 1995; Konar and Cohen 1997; Marshall and Mayer 1991). In the last decade, consumers have increasingly demanded environmentally friendly products, and consumers attest consistently that the environment, broadly defined, is near the top of the list of public concerns (Portney and Stavins 2000). As consumers become more knowledgeable about companies' impacts upon the natural environment, firms are responding by marketing themselves as environmentally friendly organizations (Russo and Fouts 1997). Increased product sales, consumer satisfaction and environmental efficiency may also translate into increased shareholder gains. As the ultimate owners of a corporation, shareholders stand to profit from a firm's good environmental deeds.

While a company's proactive environmental practices may have little influence on some customers, these same customers still may be persuaded to change their purchasing decisions if a company violates environmental laws or emits high levels of toxins (Prakash 2002). For example, 33 per cent of US adults claimed to have avoided buying products, at least occasionally, from firms with poor environmental records (Ottman 1996). Moreover, when environmental crises occur, stakeholders often demand redress to improve future performance (Greening and Gray 1994; Carrol 1993; Mitroff and Shrivastava 1987). Environmental crises, such as chemical spills and accidental releases of toxic emissions, can also affect firms financially, especially for companies with more liability exposure since their deeper pockets attract additional scrutiny by regulators and by environmental groups (Arora and Cason 1996).

Regulatory and market pressures such as these may lead companies to invest in improving their environmental records because they believe that doing so will improve their image (Bansal and Clelland 2004). For these reasons, firms that obtain greater external acceptability of their perceived environmental performance may derive competitive advantage and subsequently reap greater financial rewards.

Finally, companies that improve their environmental performance faster and earlier than their competitors may also enjoy the advantages of being 'first-movers', and have a very real opportunity to receive greater purchasing preference than less environmentally conscious competitors, thus fortifying their market positions (Darnall et al. 2002). In instances such as these, customer demand may play an important role, especially for firms that have operations in Western Europe. For example, US companies that operate in Western Europe are experiencing market pressures from large corporate buyers who request that they provide them with documentation of their environmental procedures (Darnall et al. 2002). These customers recognize that environmental procedures often vary in quality and scope, which is why environmentally conscious corporate buyers now scrutinize companies' environmental processes for their potential to reduce impacts upon the natural environment. Supply chain pressure and other market-driven pressures also point to the potential financial benefits a company may derive from reducing its impacts upon the natural environment. All of these examples support the notion that companies that reduce their impacts to the natural environment benefit financially:

Hypothesis 1: *Organizations that reduce their impacts upon the natural environment benefit financially.*

Drawing on the orthodox economic argument that the current regulatory requirements are detrimental to an organization's economic performance and constrain financial opportunities (Friedman 1970; Christiansen and Haveman 1981; Conrad and Morrison 1989; Denison 1979; Jaffe and Palmer 1997; Lave 1973; Norsworthy et al. 1979), we further hypothesize that the stringency of environmental policies reduce an organization's financial performance:

Hypothesis 2: *Organizations that are governed by more stringent environmental policies accrue fewer financial benefits.*

III. WHY COMPANIES REDUCE THEIR ENVIRONMENTAL IMPACTS

Before we explore the link between a company's environmental and financial performance further, we first need to ask why a company would choose to reduce its environmental impacts. These motivations are important to address empirically because of problems associated with endogeneity. Endogeneity in this setting relates to the fact that environmental performance is an outcome that is correlated potentially with unobservable factors that may also affect an organization's financial performance.

There are several reasons why a company might choose to reduce its impacts on the natural environment that are also related to its financial performance. Institutional theory suggests that pressures external to the organization play a role. Within the environmental arena, regulatory pressures are the most frequently cited external drivers for an organization's environmental action (Arora and Cason 1996; Konar and Cohen 1997; Porter and van der Linde 1995). Regulatory pressures exist at the local, county, state, national and international levels. They also come in multiple forms and include facility mandates to apply for operating permits, to adopt specific control technology, to monitor and report on its media-specific environmental activities, to allow regulator audits of their environmental activities, and to address any emissions violations and their potential legal implications. By reducing their environmental impacts, companies may be able to decrease their emissions below the reporting thresholds, thus reducing reporting burdens and eliminating the need to purchase and install costly pollution control technologies.

Hypothesis 3: *Organizations that reduce their environmental impacts endure stronger regulatory pressures.*

From a profit-maximizing viewpoint, rational firms possessing sufficient information (regarding costs, substitute products and other factors) examine the gross benefits and costs of an environmental strategy and undertake it if the strategy offers the best net positive benefits compared to other alternatives (Henriques and Sadorsky 1996). This is because firms are driven to increase their operational efficiencies, and such a drive is the cause for their organizational action (Alchian and Demsetz 1972). As a result, organizations that believe that reducing their environmental impacts will increase their internal efficiency are more likely to take action to minimize their impact upon the natural environment. Economic arguments therefore suggest that:

Hypothesis 4: *Organizations that reduce their environmental impacts seek to increase their internal efficiencies.*

An organization's corporate headquarters imposes other institutional pressures (Oliver 1997), which are likely to affect its decision to improve the environment. Unlike single-facility organizations, multiple-facility organizations with corporate headquarters are more likely to be held accountable by shareholders. These organizations must also adhere to a reporting system whereby information and resources are transferred between the facility and the head office and vice versa. Consequently, the facility is highly dependent on the head office and is unlikely to resist its institutional demands (Oliver 1997). For these reasons, while implementing actions to improve the environment generally occur within the facility, corporate headquarters often plays a role (Darnall 2006). As such, the existence of corporate leadership is anticipated to influence an organization's financial performance opportunities:

Hypothesis 5: *Organizations that reduce their environmental impacts have stronger corporate influences.*

However, external pressures may not be the sole reason for companies to reduce their impacts on the natural environment. For instance, facilities that have dedicated a portion of their budgets to environmental research and development demonstrate a culture for proactively managing their impacts on the natural environment. Further, these facilities have a greater capacity to address environmental concerns (Porter and van der Linde 1995; Nakamura et al. 2001) and have invested in innovations that can generate knowledge capital that is critical to competitive advantage (Ghemawat 1986). Similarly, organizations that have a dedicated environmental manager are more likely to encourage employees to be environmentally proactive, and are representative of organizations that show a stronger commitment to the environment (Henriques et al. 2004). In each instance, companies that reduce their impacts to the natural environment are expected to have stronger internal competencies than companies that improve their environmental performance:

Hypothesis 6: *Organizations that reduce their environmental impacts have stronger internal competencies.*

IV. PRIOR LITERATURE EXAMINING THE ENVIRONMENTAL–FINANCIAL PERFORMANCE LINK

Empirical research on the relationship between firms' financial performance and their environmental performance has been mixed and incomplete. In considering how these studies have measured financial performance, the availability of different types of financial data has allowed for multiple measures including stock performance, pricing, sales, intangible assets, and return on sales, equity, investment and assets. However, the lack of reliable environmental performance measures has made measuring a company's environmental actions more difficult. Because it is widely accessible, the US Toxic Release Inventory (TRI) is the data source used most commonly in prior research. While TRI data are self-reported, and therefore subject to manipulation,[1] the dataset is the most comprehensive collection of information available for manufacturing facilities' toxic chemical emissions to the land, air and water.

One of the earliest studies exploring the relationship between facilities' environmental and financial performance relied on TRI data and measured firms' return on sales, assets and equity (Hart and Ahuja 1996). The authors showed that there is a positive relationship between emissions reductions and financial performance. However, there is a two-year lag until financial performance benefits are reaped. Building on this study, Russo and Fouts (1997) evaluated the return on assets for 243 US firms and found evidence and that a company's strong environmental ratings (based on compliance records, abatement expenditures, support for environmental NGOs, and other factors) improved its financial performance. By contrast, Levy (1995) studied European, North American and Japanese transnational corporations operating in the US and found no evidence of a relationship between reductions in TRI emissions and changes in returns on assets or sales, or in the growth rate of sales. Given Hart and Ahuja's (1996) findings, the lack of a relationship in Levy's study may be due to a lagged relationship between a company's TRI emissions and its financial gains, which was not considered.

Konar and Cohen (1997) also relied on TRI emissions to assess whether a firm's toxic chemical releases predicted its intangible asset values. The authors argued that intangible assets were an indicator of a firm's future earning power arising from specialized assets such as reputation, trust and patents. They found evidence that companies' emissions reductions in fact improved their intangible assets. Similarly, Cormier et al. (1993) evaluated intangible assets by considering the impact of corporate pollution on market valuation by evaluating whether water pollution discharges reduced these assets. They found weak support for the hypothesis that consumers consider the environmental track records of firms when making investment decisions.

Using event-study methods, and a similar empirical approach to Konar and Cohen (1997), Hamilton (1995) evaluated how firms' stock prices were affected in the days following negative environmental press. The results showed that stock prices fell for companies with higher published TRI releases. However, the level of emissions did not affect changes in stock returns. These findings suggest that stockholders do not differentiate among the companies having to report TRI emissions and only react to the fact that companies' TRI pollutants were large enough to be reported to the EPA.

Also relying on event-study methodologies, Klassen and McLaughlin (1996) demonstrated that public announcements about whether firms had won environmental awards or experienced environmental crises were indicators of their environmental performance. The authors also showed that companies with stronger environmental management (as indicated by their environmental awards) had a higher stock price. Significant negative returns were further documented after firms had an environmental crisis, adding further empirical support for a link between environmental and financial performance.

Using the same event-study methodology, Laplante and Lanoie (1994) found evidence that 'environmental news' (publication of lists of non-compliers and heavy emitters) did not affect equity prices. Lanoie et al.'s (1998) results did not confirm the general findings put forward by Konar and Cohen (1997), Hamilton (1995), Klassen and McLaughlin (1996), Laplante and Lanoie (1994) and Russo and Fouts (1997). However the sample was small and could have led to their inconclusive results because smaller samples bias statistical estimates such that it is difficult to find a statistical relationship (Hoenig and Heisey 2001; Gillett 1989). Laplante and Lanoie (1994) also used event-study methodology to evaluate the effects of four types of environmental news (publication of lawsuits, settlements, environmental incidents, and investments in pollution abatement equipment) in Canada between 1982 and 1991. Settlements and investments had negative effects on firms' financial performance, but lawsuits and incidents had no effect.

Cohen et al. (1995) took a different approach by examining the environmental performance of *Standard and Poor's 500* companies. The companies were classified into high-pollution and low-pollution firms using an index of nine variables. Their results showed that firms with lower pollution portfolios achieved higher returns in some instances. Similarly, Stanwick and Stanwick (2000) examined a sample of 469 *Forbes 500* companies to determine if environmental disclosures were related to their net income. Firms were classified as low, medium or high environmental performers based on their disclosures, and the authors showed that firms classified as high financial performers had higher incidences of environmental commitment than low financial performers. Firms classified as medium financial performers had the highest environmental commitment; possibly indicating that they were trying to seek a competitive advantage in the market place.

Using a subset of the TRI (that is, 33/50 chemicals),[2] Khanna and Damon (1999) evaluated whether firms' emissions of toxic 33/50 chemicals had a negative effect on their financial performance. They measured financial performance by a firm's return on investment and the ratio of the valuation of intangible assets relative to sales. Using a Heckman selection model, the authors showed that 33/50 chemical emissions had a negative effect on return on investment, but a positive effect on intangible assets relative to sales. Since return on investment is an indicator of short-run performance and intangible assets relative to sales measures long-run performance, the authors confirmed Hart and Ahuja's suggestion that firms benefit financially in the long run by reducing their environmental impacts, even if they lose in the short run. Arora and Cason (1996) also evaluated the financial performance of 33/50 participants and showed similar results in that profit increased slightly for companies in the voluntary environmental programme.

Finally, Rivera (2002) examined a cross-section of 164 Costa Rican hotels to determine if voluntary participation in a sustainable tourism certification programme increased participants' hotel price and sales. Hotels participating in the programme that demonstrated significant environmental improvements derived price premiums and increased sales.

In summary, the results from prior research suggest that there appears to be a positive relationship between a firm's environmental actions and its financial performance (see Table 6.1). These findings are not significant when evaluating short-run financial effects on stock market valuations, but they are when taking a longer view (up to three years after the fact). While these results are encouraging, it is important to recognize that many estimation models used in previous studies did not consider that a firm's environmental performance is endogenous. That is, it is difficult to determine whether a firm's environmental performance improved because it was more efficient at the onset, which in turn fuelled its greater financial gains in the long run.

We therefore can be tempted to conclude that reducing a company's environmental impact leads to improved financial performance. However, this conclusion may be false. In fact, we do not know whether improved financial performance is due to environmental improvements, or due to the fact that the company already has good management practices prior to the reduction of its environmental impacts. Studies undertaken which do not correct for endogeneity can cause misleading results. Therefore, the results of most prior studies must be interpreted with care and additional studies are needed to evaluate these relationships further.

An additional limitation of each of the aforementioned studies is that they evaluated firms either in the US or in Canada, and in one case Costa Rican firms were considered. As yet, no study has considered the environmental–financial performance relationship among companies across different countries. This issue is particularly important since many more companies now operate globally.

Table 6.1 Summary of prior studies evaluating the link between environmental and financial performance

Study	Financial performance measures	Environmental performance measures	Relationship	Endogeneity and/or selection bias addressed?
Arora and Cason (1995)	ROA	33/50 TRI emissions	Positive relationship	No
Cohen et al. (1995)	ROA, ROE, Total return to shareholder	High pollution vs. low pollution firms based on nine variables	Generally positive, with lower pollution portfolios achieving higher returns in some instances	No
Cormier et al. (1993)	Intangible asset values	Water pollution discharges	Weak negative relationship	No
Hamilton (1995)	Stock price	TRI publication, TRI emissions	Negative relationship for TRI publication; no relationship for amount of emissions	Yes
Hart and Ahuja (1996)	ROS, ROA, ROE	TRI	Positive relationship in year 2	No
Khanna and Damon (1999)	ROI, Ratio of the valuation of intangible assets/sales	33/50 TRI emissions	Negative relationship with ROI; Positive relationship with intangible assets/sales	Yes
Klassen and McLaughlin (1996)	Stock market performance	Environmental performance awards	Positive returns for first-time environmental performance award winners; negative returns for environmental crises	–
Konar and Cohen (1997)	Intangible asset values	TRI, Environmental lawsuits	Positive relationship for both measures	–
Laplante and Lanoie (1994)	Firms' equity value	Lawsuits, settlements, environmental incidents, investments in pollution abatement equipment	Negative relationship with settlements and investments	–
Levy (1995)	ROS, ROA, Growth	TRI	No relationship	No

Lanoie et al. (1998)	Equity prices	Publication of non-compliers and heavy pollution emitters	No relationship, but sample was small	–
Rivera (2002)	Hotel room price and sales	Participation in voluntary environmental program	Positive relationship	Yes
Russo and Fouts (1997)	ROS	Compliance, abatement expenditures, support for NGOs	Positive relationship	No
Stanwick and Stanwick (2000)	Net income controlled by firm size	Formal environmental policy or description of environmental commitment	Positive relationship	No

Note:
– = Relied on an event-history model and so endogeneity related to temporal ordering was not an issue.

We address these issues by considering the relationship between facilities' environmental performance and financial performance. Our empirical estimations control for endogeneity, thereby offering more robust evidence about whether organizations accrue financial benefits from their proactive environmental actions. This study also takes an important step by considering these relationships in the international context to provide a more complete view of the association between financial and environmental performance.

V. RESEARCH METHODS

To evaluate our hypotheses, we relied on data from a 12-page postal survey implemented by the OECD Environment Directorate and researchers from Canada, France, Germany, Hungary, Japan, Norway and the US (see Chapter 1 for a discussion).

Assessing the Determinants of Financial Performance

To measure a company's financial performance, the OECD survey asked facility managers whether the company's profits had changed over the past three years. Respondents replied using a five-point scale indicating whether their revenue was 'so low as to produce large losses', 'insufficient to cover our costs', 'at break even', 'sufficient to make a small profit' or 'well in excess of costs'. The survey also asked facility managers whether the value of their shipments had changed over the last three years. Respondents replied using a similar scale to indicate whether their value of shipments had 'significantly decreased', 'decreased', 'stayed about the same', 'increased' or 'significantly increased'. We then combined the first three and the last two categories of each variable to account for whether or not the facility had earned positive profits and increased shipment values during the last three years.

To measure whether or not companies had reduced their impact upon the natural environment, the OECD survey asked managers if their facility had experienced a change in their environmental impacts per unit of output in the last three years. Facility managers reported their environmental changes for five different impacts: use of natural resources (energy, water, and so on); solid waste generation; wastewater effluent; local or regional (neighbouring countries) air pollution; and global pollutants (greenhouse gases). Managers indicated whether their impacts had 'decreased significantly', 'decreased', incurred 'no change', 'increased' or 'increased significantly'.

We combined the five environmental performance measures into an environmental performance index using factor analysis with orthogonal varimax rotation (Cronbach's alpha = 0.73).[3] Doing so allowed us to assess how a company's overall environmental performance affected its financial prospects. The results of our factor analysis yielded one factor with similar loadings, thus indicating that each of our five indicators measured the same underlying construct. In addition to the environmental impact index, we estimated the five environmental performance measures separately.

Because companies are subject to a variety of regulatory frameworks that may affect their financial performance opportunities, the survey asked facilities to describe the environmental policy regime to which they were subject. In order to obtain an assessment of the perceived stringency of the regulatory regime, respondents were requested to indicate whether it was 'not particularly stringent, obligations can be met with relative ease', 'moderately stringent, requires some managerial and technological responses' or 'very stringent, has a great deal of influence on decision-making within the facility'.

In order to address firm heterogeneity and heterogeneity across countries, the OECD survey included numerous control variables that are thought to predict a company's ability to improve its financial performance. To measure the concentration of the market in which the facility operated, the survey accounted for whether the facility had less than five competitors, whether it had between five and ten competitors, or whether it had greater than ten competitors. Facilities having more than ten competitors were our omitted reference category. To control for economies of scale associated with organizational size, and the fact that larger organizations are more likely to possess the knowledge-based skills that may be critical factors in their capacity to commit to environmental initiatives (Hart and Ahuja 1996), the survey included a variable for the number of employees within the firm. The survey also accounted for the facility's primary customer, and whether the customer was at the end of the supply chain, or in the middle of the supply chain. Companies that had consumers at the end of the supply chain were our omitted reference category.

To measure export orientation, the OECD survey asked respondents to indicate whether the facility's market was primarily at a local, national, regional or global level (Nakamura et al. 2001). Global market operations were our omitted reference category. We also controlled for whether companies were accountable to shareholders. For companies that operated internationally, the survey asked whether or not their head office was located in a foreign company.

Finally, because this study compared facilities in multiple countries, it was important to control for heterogeneities across these countries. We included a series of dummy variables to account for the country in which the facility operated (Canada, France, Germany, Hungary, Japan, Norway and the US). Our reference dummy variable was the US. We also created ten aggregated industrial sector dummies to control for variations across industrial sectors. In this case, our reference dummy sector was non-metallic mineral products.

Assessing the Determinants of Improved Environmental Performance

Regulatory pressures were assessed by asking environmental managers how important the influence of public authorities was on their environmental practices, whether preventing or controlling environmental accidents was a significant motivation on their production practices, and whether achieving regulatory compliance was a significant influence on the environmental practices of their facility. Managers indicated whether each was 'not applicable', 'not important', 'moderately important' or 'very important'. 'Not applicable' and 'not important' responses were combined. As noted above, respondents were also asked to describe how they perceived the environmental policy regime to which they were subject by indicating whether it was 'not particularly stringent, obligations can be met with relative ease', 'moderately stringent, requires some managerial and technological responses' or 'very stringent, has a great deal of influence on decision-making within the facility'. We combined the four regulatory pressures into an index using factor analysis with orthogonal varimax rotation. Doing so allowed us to assess how a facility's overall regulatory pressures affected its decision to reduce its environmental impacts. The results of our factor analysis yielded one factor with similar loadings, thus indicating that each of our four indicators measured aspects of the same construct (alpha = 0.70).

To account for the extent to which organizations were efficiency-driven (Alchian and Demsetz 1972) with respect to the environment, the survey asked facility managers they how important it was for them to achieve cost savings due to environmental practices. Facility managers reported whether these influences were 'not important', 'moderately important', 'very important' or 'not applicable'. 'Not applicable' and 'not important' responses were then combined. Using the same scale, institutional pressures imposed by the facility's head office (Oliver 1997) were measured by asking facilities how important they considered the influence of corporate headquarters on the environmental practices of their facility.

Innovation investments generate knowledge capital that is critical to competitive advantage (Ghemawat 1986). The OECD survey measured these competencies by whether or not the facility had a research and development budget allocated towards environmental matters (Porter and van der Linde 1995; Nakamura et al. 2001). Because organizations that have an environmental manager are more likely to encourage employees to be environmentally proactive (Welford 1998), the survey asked facilities whether they had a dedicated person responsible for the facility's environmental affairs.

Finally we controlled for heterogeneities across the ten industrial sector dummies by including a series of dummy variables. In this case, our reference dummy sector was non-metallic mineral products. We also accounted for size and country-level differences by incorporating the number of employees per facility, in addition to seven dummy variables to account for the country in which the facility operated (Canada, France, Germany, Hungary, Japan, Norway and the US).

Empirical Models

The relationship between facilities' financial and environmental performance was first evaluated using chi-square and analysis of variance statistical techniques. To model our two interrelated binary outcomes (improved financial and environmental performance) we also relied on bivariate probit estimation with robust variances. This simultaneous equations approach controls for endogeneity (Ashford and Snowden 1970; Greene 1993) related to the fact that the same unobservable factors may be the reason why a facility improves its environmental and financial performance. Such an approach represents an important improvement on the existing probability models that evaluate the environmental–financial performance link based on single-equation estimation.

A bivariate probit model assumes that predicting financial performance and environmental performance are separate, but interrelated. The interrelation takes place through a correlated error structure so that, after controlling for explanatory variables, the two outcomes are related. The model relies on a simultaneous estimation approach in which the factors that determine an organization's environmental performance are estimated simultaneously with the factors that determine its financial performance. The two equations are jointly estimated using maximum likelihood.

To determine this inter-relationship, the bivariate probit model produces 'rho', which, if statistically different from zero, indicates that a relationship exists between the two outcome variables and that a simultaneous estimation procedure is needed. In all but one application of the bivariate probit estimations, our first-stage model estimation produced a rho that was statistically significant, therefore indicating that endogeneity existed and that relying on a two-stage estimation procedure was critical to our estimations.

Sector Analysis

In a complementary set of analyses, we evaluated whether sectors with different environmental characteristics improved their financial performance. We made three types of comparisons. First we compared the financial performance of facilities operating within low-polluting industries or 'clean sectors' to facilities operating within high-polluting industries or 'dirty sectors'. To classify facilities within these sectors, we relied on a taxonomy of manufacturing companies operating in the US that was developed by the World Bank (Mani and Wheeler 1997) and Gallagher and Ackerman (2000).[4] 'Clean' sectors were characterized as facilities operating within the fabricated metal products, industrial machinery, electronics, transportation equipment, instrumentation, and textile sectors (ISICs 17, 28, 29, 31, 33, 35). 'Dirty' sectors included pulp and paper, chemical, petroleum refining, primary metal and basic metal industries (ISICs 21, 24, 26, 27). The environmental and financial performance of companies operating within these two types of manufacturing industries was then compared.

In the second stage of our sector analysis, we assessed whether facilities operating within two 'dirty' sectors differed in their environmental performance and whether these differences were related to their financial performance. More specifically, we compared whether facilities within the chemical industry that accrued positive profits and increased the value of their shipments also implemented different environmental practices and reduced their environmental impacts to a greater extent than companies operating in the pulp and paper sector. The chemical industry was selected because it has been seeking voluntarily to reduce its impacts upon the environment since the 1980s in an effort to improve its overall environmental performance and public image (King and Lenox 2001; Hart and Ahuja 1996). For this reason, we classified the chemical industry as an 'early environmental mover'. By contrast, the pulp and paper industry began voluntarily reducing its environmental impacts across the entire sector at a much later time (Hart and Ahuja 1996), making it a 'late environmental mover'. The relationship between environmental and financial performance of companies operating within these two sectors was then compared.

Finally, we considered whether companies operating in 'high-growth' industries differed from companies operating in 'low-growth' sectors in whether they derived positive financial benefits from their environmental actions. This last sector-level analysis was motivated by prior research suggesting that industry growth facilitates the financial benefits that an organization derives from its environmental improvements (Russo and Fouts 1997). According to Russo and Fouts, industry growth moderates the relationship between environmental and economic performance for several reasons. First, industry growth accelerates the maturation of technologies within that industry and as a result firms that invest in pollution prevention have a higher prospective return than firms in low-growth industries. The argument here is that the newness of the capital stock improves a company's financial and environmental performance. Moreover, high-growth industries have a more dynamic (rather than bureaucratic) management style, and may therefore capture additional financial benefits by going beyond compliance because of their innovative culture. Finally, Russo and Fouts (1997) argue that is easier to create a reputation for environmental stewardship in a high-growth industry rather than a low-growth industry.

To determine which companies operated in high- and low-growth sectors, we assessed whether or not they experienced a change in the value of their shipments. The number of managers within each industry who indicated that their value of shipments had 'significantly decreased' were summed and multiplied by 1. Similarly, the number of respondents who indicated that their value of shipments had 'decreased', 'stayed about the same', 'increased' or 'significantly increased' were summed and multiplied by 2, 3, 4 and 5, respectively. All values were summed to create an 'industry score' for each industrial sector represented in the data. Industry scores were then divided by the number of respondents within each respective industry to create a weighted score. Companies operating in sectors with the largest weighted score (food) were considered high-growth industries, whereas sectors with the lowest score (electronics) were considered low-growth industries.

To assess the statistical relationship between facilities' financial and environmental performance among the sector comparisons, we relied on chi-square statistical tests.

VI. RESULTS

Hypothesis 1: *Organizations that reduce their impacts upon the natural environment benefit financially.*

In all instances, the proportion of facilities that improved their business performance and that reduced their impacts upon the natural environment was greater than the proportion of companies that improved their business performance, but did not reduce their environmental impacts (see Table 6.2). With respect to our index of environmental impacts, our results showed that more than 99 per cent of the time there was a statistically significant difference between a facility's mean reduction in environmental impacts and its positive business performance. However, this relationship was less consistent when considering the value of a facility's shipments.

Table 6.2 Relationship between financial performance and decreases in environmental impacts

Significant decrease or decrease in the following environmental impacts†	Business performance		Value of shipments	
	Improved	p-value	Improved	p-value
Index of environmental impacts (n = 1923, 1934)	11.32††	0.001***	0.35	0.557
Use of natural resources (energy, water, etc.)	61%	0.044**	34%	0.549
(n = 3475, 3506)	58%		35%	
Solid waste generation	62%	0.032**	32%	0.034**
(n = 3521, 3551)	58%		35%	
Wastewater effluent	62%	0.047**	35%	0.028**
(n = 3154, 3179)	58%		32%	
Local or regional air pollution	64%	0.009***	35%	0.090*
(n = 2738, 2756)	59%		32%	
Global pollutants (e.g. greenhouse gases)	62%	0.082*	35%	0.042**
(n = 2214, 2227)	58%		31%	

Notes:
† Top values represent facilities decreased their environmental impacts. Bottom values represent facilities that did not decrease their impacts. P-values are from Chi-square tests.
†† Represents results from analysis of variance F tests, which is why % improvements do not apply.
* Statistically significant at $p \leq 0.10$; ** Statistically significant at $p \leq 0.05$; *** Statistically significant at $p \leq 0.01$.

More specifically, there was a statistically significant difference between a facility's positive business performance and its reductions in solid waste, local and regional air pollution, and global pollutants, but not for natural resource use.

With respect to the bivariate probit analysis results, our estimations showed that in fact environmental performance was endogenous, as illustrated by the Wald test of rho (see Appendix Tables 6A.1–6A.4). In all but one instance, the rho statistic was statistically significant, indicating that estimating the reasons why companies reduce their environmental impacts was critical to understanding why a company's environmental and financial performance are related. After controlling for endogeneity, the findings suggested that a company's reported environmental performance was related to whether or not it earned positive profits, and whether or not it increased the value of its sales (see Appendix Tables 6A.1–6A.2).

Table 6.3 Relationship between financial performance and perceived policy stringency

Environmental policy regime†	Business performance		Value of shipments	
	Improved	p-value	Improved	p-value
Perceived to be very stringent	64%	0.000***	37%	0.000***
(n = 3829, 3857)	52%		28%	

Notes:
† Top values represent facilities that believed the environmental policy regime was moderately or very stringent. Bottom values represent facilities that believed the environmental policy regime was not stringent.
* Statistically significant at $p \leq 0.10$; ** Statistically significant at $p \leq 0.05$; *** Statistically significant at $p \leq 0.01$.

Facilities that reduced their wastewater and air pollution had the greatest probability of earning positive profits. Similarly, facilities that reduced their global pollutants had the greatest probability of increased value of sales. These findings offer evidence in support of Hypothesis 1, which states that organizations that reduce their impacts upon the natural environment benefit financially.

Hypothesis 2: *Organizations that are governed by more stringent environmental policies accrue fewer financial benefits.*

The results indicated that facilities which improved their business performance reported more often that they believed the environmental policy regime was moderately or very stringent (see Table 6.3). For instance, 64 per cent of facilities that improved their business performance reported that the environmental policy regime was very stringent. By contrast 52 per cent of facilities that improved their business performance reported that the environmental policy regime was not stringent. Similar relationships were found for value of shipment improvements. However, in evaluating these relationships, we have not controlled for the fact that many of these facilities that reduced their environmental impacts (due to regulatory pressures) may be the ones that improve their financial performance more.

When evaluating the bivariate probit results, additional evidence was provided for our hypothesized relationships. While a facility's improved environmental performance yielded greater positive profits and increased value of sales, these benefits were diminished by the perceived stringency of the environmental regulatory regime. More specifically, companies that reported that the environmental regulatory regime was more stringent also reported that they had diminished their profits, and to a lesser extent, decreased the value of their sales. These results provide evidence in support of Hypothesis 2, which suggests that organizations that are governed by more stringent environmental policies accrue fewer financial benefits.

This pattern did not convey to facilities' value of shipments in that facility managers who reported that the environmental policy regime was more stringent also reduced the value of their shipments, but the relationship was weak. Only one model (of six) showed a weak statistical relationship ($p < 0.10$) with the stringency of the regulatory regime.

With respect to our control variables, facilities with more workers were more likely to both earn positive profits and increase the value of their shipments. Also, companies operating at the end of the supply chain, and thus producing goods for final consumption, were more likely to earn positive profits, as were companies operating in markets with fewer competitors. Facilities with a local market focus were less likely to earn positive profits and increase the value of their sales than companies operating at the international level, and companies with a national market focus were less likely to increase their value of sales than companies operating at the international level.

In comparing how facilities performed by country, Canadian, French, Hungarian and to a lesser extent some German and Norwegian facilities all reported shipment values had increased more than US facilities, whereas Japanese facilities reported having decreased shipment values in comparison to US entities. Similarly, US facilities reported that they failed to accrue positive profits to the same extent as Canadian or Hungarian facilities, although they fared better than Japanese organizations. Finally, industrial sector had no relationship with facilities' financial performance.

Hypothesis 3: *Organizations that reduce their environmental impacts face stronger regulatory pressures.*

In evaluating the reasons why the facilities in this study reduced their environmental impacts, regulatory pressures appear to have played a strong role. In all instances, the proportion of facilities that had reported a decrease in their environmental impacts also reported being subject to a higher degree of regulatory pressure (see Table 6.4). More specifically, for each of our environmental impact measures, our results showed that there was a statistically significant difference between a facility's mean reduction in environmental impacts and its degree of regulatory pressure.

These results were corroborated by our bivariate probit analyses (see Appendix Tables 6A.1–6A.2). Regulatory pressures were associated with whether companies reduced their environmental impacts in all instances except for reductions in solid waste impacts. Despite the finding that a more

Table 6.4 Relationship between decreases in environmental impacts and regulatory pressures

Significant decrease or decrease in the following environmental impacts	F-statistic	p-value
Index of environmental impacts (n = 1868)	3.46†	0.001***
Use of natural resources (energy, water, etc.) (n = 3258)	1.61	0.002***
Solid waste generation (n = 3294)	1.47	0.001***
Wastewater effluent (n = 2990)	2.65	0.000***
Local or regional air pollution (n = 2652)	3.32	0.000***
Global pollutants (e.g. greenhouse gases) (n = 2149)	1.80	0.001***

Notes:
† Represents t-test statistic.
* Statistically significant at $p \leq 0.10$; ** Statistically significant at $p \leq 0.05$; *** Statistically significant at $p \leq 0.01$.

stringent regulatory regime was related to a reduced probability that the facilities earned positive profits, pressure from regulators appears to have been an important motivator that encouraged companies to reduce their environmental impacts.

Hypothesis 4: *Organizations that reduce their environmental impacts seek to increase their internal efficiencies.*

With respect to other motivations for reducing environmental impacts, the desire to increase opportunities for cost savings had an important role (see Table 6.5). For example, 50 per cent of facilities that decreased their environmental impacts also reported that opportunities for cost savings related to environmental activities were very important to their operations. By contrast, 43 per cent of facilities that did not decrease their environmental impacts related to natural resources and also believed that opportunities for cost savings were very important to their operations. Similar results were found for our other environmental impact measures as well as for our bivariate probit modes, offering support for Hypothesis 4.

Hypothesis 5: *Organizations that reduce their environmental impacts have stronger corporate influences.*

Our results also showed that the influence of pressures from corporate headquarters also had a statistically significant relationship with whether

Table 6.5 Relationship between decreases in environmental impacts and opportunities for cost savings and influences from corporate headquarters

Significant decrease or decrease in the following environmental impacts†	Opportunities for cost savings		Influences from corporate headquarters	
	Very important influence	p-value	Very important influence	p-value
Index of environmental impacts (n = 1941, 1630)	11.82††	0.000***	34.27††	0.000***
Use of natural resources (energy, water, etc.)	50%	0.000***	53%	0.000***
(n = 3481, 2888)	43%		43%	
Solid waste generation	50%	0.000***	51%	0.000***
(n = 3523, 2910)	43%		44%	
Wastewater effluent	50%	0.001***	54%	0.000***
(n = 3166, 2644)	45%		44%	
Local or regional air pollution	52%	0.022**	58%	0.000***
(n = 2754, 2290)	46%		44%	
Global pollutants (e.g. greenhouse gases)	53%	0.002***	59%	0.000***
(n = 2231, 1848)	45%		53%	

Notes:
† Top values represent facilities decreased their environmental impacts. Bottom values represent facilities that did not decrease their impacts. P-values are from Chi-square tests.
†† Represents results from analysis of variance statistical tests.
* Statistically significant at $p \leq 0.10$; ** Statistically significant at $p \leq 0.05$; *** Statistically significant at $p \leq 0.01$.

or not facilities reduced their environmental impacts, offering evidence that supports Hypothesis 5. More specifically, 53 per cent of facilities that reduced their use of natural resources also reported strong influences from corporate headquarters, compared to 43 per cent of facilities that did not reduce their environmental impacts, but still reported strong corporate influences (see Table 6.5). These relationships were confirmed in our bivariate probit regressions.

Hypothesis 6: *Organizations that reduce their environmental impacts have stronger internal competencies.*

Facilities that had budgets for environmental research and development more frequently reduced their impact to the natural environment, as did

Table 6.6 Relationship between decreases in environmental impacts and opportunities for cost savings and influences from corporate headquarters

Significant decrease or decrease in the following environmental impacts†	Budget for environmental R&D		Person in charge of environmental affairs	
	Yes?	p-value	Yes?	p-value
Index of environmental impacts (n = 1952, 1998)	31.44††	0.000***	89.58††	0.000***
Use of natural resources (energy, water, etc.)	12%	0.000***	81%	0.000***
(n = 3532, 3609)	8%		67%	
Solid waste generation	13%	0.000***	80%	0.000***
(n = 3576, 3654)	6%		66%	
Wastewater effluent	12%	0.001***	83%	0.000***
(n = 3204 , 3276)	9%		69%	
Local or regional air pollution	14%	0.000***	83%	0.000***
(n = 2772, 2839)	9%		73%	
Global pollutants (e.g. greenhouse gases)	15%	0.000***	86%	0.000***
(n = 2246, 2297)	9%		72%	

Notes:
† Top values represent facilities decreased their environmental impacts. Bottom values represent facilities that did not decrease their impacts. P-values are from Chi-square tests.
†† Represents results from analysis of variance statistical tests.
* Statistically significant at $p \leq 0.10$; ** Statistically significant at $p \leq 0.05$; *** Statistically significant at $p \leq 0.01$.

facilities that had a person in charge of their organization's environmental affairs (see Table 6.6). For instance, 12 per cent of facilities that had a budget for research and development decreased their environmental impact as compared to 8 per cent of facilities that did not decrease their environmental impacts, but had an R&D budget. Similarly, 81 per cent of facilities that had a person in charge of environmental affairs reported a decrease in their environmental impacts as compared to 67 per cent of facilities that did not decrease their environmental impacts, but had a person in charge of environmental affairs. These relationships were further validated by the results of our bivariate probit regressions, offering additional support for Hypothesis 6, which states that organizations that reduce their environmental impacts have stronger internal competencies.

In summary, the findings of our multivariate analyses offer evidence for Hypotheses 1–6. While these results are encouraging, our data are cross-sectional, which makes it difficult to determine the causal link between our variables of interest. Even determining the direction of prediction is a challenge. For example, we know a statistically significant relationship exists between environmental performance and financial performance, but we cannot determine whether a company's improved environmental performance occurred prior to its improved financial performance. As a result, the strength of our findings is tempered to a certain degree. However, our methodological approach was an improvement over previous studies in that it controlled for endogeneity associated with the relationship between environmental and financial performance. This study is also the first of its kind to consider these issues across a cross-section of countries.

The next section of this chapter offers a more in-depth sector-level analysis that considers whether different facilities operating within some industrial sectors benefited financially more than facilities operating in other sectors.

VII. SECTORAL ANALYSIS

In the previous section we found significant statistical relationships between a company's environmental and financial performance. This section considers these relationships in greater detail using a targeted sectoral analysis. We began this analysis by first considering how the environmental–financial performance relationship differed for companies operating in 'clean' industrial sectors and in 'dirty' industrial sectors.

Does the Environmental–Financial Performance Relationship Differ among 'Dirty' and 'Clean' Sectors?

In assessing the relationship between facilities' environmental and financial performance across dirty and clean sectors, we hypothesized that larger financial benefits would accrue to facilities operating in dirtier industries that also reduced their environmental impacts. Our rationale was that these companies could reduce their impacts upon the natural environment at a lower cost because they have more 'low-hanging fruit' that can be picked more easily. However, achieving the same environmental improvements for companies operating in cleaner industrial sectors would cost significantly more. As a result, the positive profit for environmental actions taken by facilities operating in clean sectors was expected to be less.

Relying on Mani and Wheeler (1997) and Gallagher and Ackerman's (2000) classification of 'clean' and 'dirty' manufacturing sectors, we assessed whether the relationship between environmental and financial performance differed. In evaluating environmental performance, we assessed whether or not companies reduced their environmental impacts. Table 6.7 compares

Table 6.7 Relationship between financial performance and clean versus dirty sectors[+]

Facility Characteristic	Profit[†] positive/break-even or negative
Clean sector	31.7%***
(n = 3939; n = 3966)	36.8%
Dirty sector	30.8%***
(n = 3939; n = 3966)	26.4%

Notes:
[+] Clean sectors are ISICs 17, 28, 29, 31, 33, and 35. Dirty sectors are ISICs 21, 24, 26 and 27.
[†] Top values represent facilities that earned positive profits the past three years and that operated in a particular sector. Bottom values represent facilities that did not accrue positive profits and operated from the same sector.
* Statistically significant at $p \leq 0.10$; ** Statistically significant at $p \leq 0.05$; *** Statistically significant at $p \leq 0.01$.

whether clean sectors differed from dirty sectors in their ability to earn positive profits. The results showed that a greater proportion of more facilities that accrued positive profits operated in dirty sectors, as compared to the proportion of facilities that did not earn positive profits and operated in the same sectors. Approximately 4.4 per cent more companies that earned positive profits operated in dirty sectors. By contrast, about 5 per cent fewer companies earned positive profits and operated in cleaner sectors.

To consider these relationships further, we compared companies' environmental practices to their financial performance. In comparing differences among the clean sectors and the dirty sectors, companies operating in dirty sectors reduced their environmental impacts proportionately to clean sector companies (see Table 6.8). For example, 54.3 per cent of companies in dirty sectors that earned positive profits reported that they also had reduced their use of natural resources. Similarly, 54.5 per cent of clean sector facilities that accrued positive profits also reduced their impacts to natural resources.

In comparing differences within the clean sectors and the dirty sectors, in only one instance did facilities that operated in dirty sectors, and that accrued positive profits, also reduce their impact upon the natural environment. More specifically, 58.5 per cent of companies in dirty sectors that earned positive profits reported that they also had reduced their solid waste generation. Clean sector facilities that earned positive profit did not reduce their impacts upon natural resources, solid waste, wastewater, air pollution and global pollutants any more than facilities in the same sectors that did not accrue positive profits. In sum, our findings indicate that there was no statistically

Table 6.8 Relationship between clean/dirty sectors+ with positive financial performance and reduction in environmental impact

Reductions in	Facility comparisons†	
	Profit in clean sectors positive/breakeven or negative (%)	Profit in dirty sectors positive/breakeven or negative (%)
Use of natural resources	54.5	54.3
(n = 1129, 1032)	50.8	52.1
Solid waste generation	56.1	58.5*
(n = 1151, 1044)	55.3	52.4
Wastewater effluent	39.6	46.2
(n = 1003, 949)	38.4	43.0
Local or regional air pollution	39.8	46.4
(n = 850, 853)	35.3	44.0
Global pollutants	35.7	36.1
(n = 684, 699)	34.8	33.2

Notes:
+ Clean sectors are ISICs 17, 28, 29, 31, 33 and 35. Dirty sectors are ISICs 21, 24, 26 and 27.
† Top values represent facilities within the sector that earned positive profits during the past three years and that indicated they had reduced their environmental impacts. Bottom values represent facilities within the sector that had did not accrue positive during the past three years and that reported reduced environmental impacts.
* Statistically significant at $p \leq 0.10$; ** Statistically significant at $p \leq 0.05$; *** Statistically significant at $p \leq 0.01$.

significant relationship between facilities' positive financial performance and their environmental performance in both the 'dirtiest' and 'cleanest' sectors over the last three years. It is important to note, however, that within dirty and clean sectors, there are likely to be differences in the extent to which companies have reduced their environmental impacts. As such, high environmental performers may be pooled with low environmental performers within each sector. These differences may create the appearance that cleaner facilities do not benefit financially. For this reason, in addition to drawing comparisons across dirty and clean sectors, future research should study the extent to which companies differ within these sectors.

Does the Environmental–Financial Performance Relationship Differ between 'Early Movers' and 'Late Movers'?

In comparing facilities that operated in 'early environmental mover' sectors and 'late environmental mover' sectors, we compared whether companies within the chemical industry derived greater financial benefits from their environmental actions than companies operating in the pulp and paper sector (Hart and Ahuja 1996). These sectors were chosen because the chemical industry has been participating in voluntary environmental programmes since the 1980s to improve its overall environmental performance (Khanna and Damon 1999). We therefore defined these companies as 'early movers' within the most polluting industries when it came to addressing their environmental impacts. By contrast, the pulp and paper industry began at a later time to consider voluntarily reducing its environmental impacts across the entire sector (Hart and Ahuja 1996). For this reason, we considered it a 'late mover' among the most polluting manufacturing sectors when it came to reducing its environmental impacts. The environmental and financial performance of companies operating within these two sectors was then compared.

Our hypothesis was that late movers would derive more low-cost environmental improvements (Hart and Ahuja 1996), and therefore reap greater financial benefits than early movers. By contrast, early movers would already have collected the benefits of their low-cost environmental improvements. As a result, their 'low-hanging fruit' would have long since been picked, and they would be less likely to derive a financial benefit from their environmental improvements. This hypothesis is based on the notion that there are diminishing returns on environmental actions.

The results of our chi-square analyses showed that there were no statistical differences among early or late movers and whether their reduced impacts to the natural environment were associated with earning positive profits (see Table 6.9).

There also was no consistent pattern suggesting that late movers who accrued positive profits and reduced their environmental impacts did so more frequently than early movers. However, it is important to note that this study evaluated facilities' activities for one point in time, and would benefit from data that were collected at over multiple time periods. Time series panel data would allow us to compare facility responses longitudinally and determine the temporal ordering of specific events. Such information would offer more rigorous evidence for the relationships we have studied.

Relationships between Financial Performance and Environmental Actions among 'Low-Growth' and 'High-Growth' Industries

In the final component of our sector analysis, we considered whether companies operating in 'high-growth' industries differed from companies operating in 'low-growth' sectors in whether they derived positive financial benefits from their environmental actions. This analysis was motivated by prior research suggesting that industry growth facilitates the financial

Table 6.9 Relationship between early- and late-mover sectors+ with positive financial performance and reduction in environmental impact

Reductions in	Facility comparisons†	
	Profit for early movers positive/break-even or negative (%)	Profit for late movers positive/break-even or negative (%)
Use of natural resources	53.0	55.0
(n = 262, 126)	50.6	67.4
Solid waste generation	54.9	59.2
(n = 266, 129)	47.6	60.4
Wastewater effluent	46.8	52.6
(n = 250, 121)	43.0	62.2
Local or regional air pollution	50.9	42.7
(n = 233, 110)	50.0	50.0
Global pollutants	39.2	35.7
(n = 188, 95)	28.6	43.6

Notes:
+ Early movers are chemical companies in ISIC 24. Late movers are pulp and paper companies in ISIC 21.
† Top values represent facilities within the sector that earned positive profits during the past three years and that indicated they had reduced their environmental impacts. Bottom values represent facilities within the sector that had did not accrue positive during the past three years and that reported reduced environmental impact.
* Statistically significant at $p \leq 0.10$; ** Statistically significant at $p \leq 0.05$; *** Statistically significant at $p \leq 0.01$.

benefits an organization derives from its environmental improvements (Russo and Fouts 1997).

According to Russo and Fouts (1997), industry growth moderates the relationship between environmental and economic performance for several reasons. First, industry growth accelerates the maturation of technologies within that industry and as a result, firms that invest in pollution prevention have a higher prospective return than firms in low-growth industries. The argument is that the newness of the capital stock improves a company's financial and environmental performance. Moreover, high-growth industries have a more fluid management style, and may capture additional gains by going beyond compliance because of their innovative culture. Finally, it is easier to create a reputation for environmental stewardship in a high-growth industry than in a low-growth industry.

To determine which companies operated in high- and low-growth sectors, the OECD survey asked respondents whether or not they experienced a

Table 6.10 Relationship between low- and high-growth sectors⁺ with positive financial performance and reduction in environmental impact

Reductions in	Facility comparisons†	
	Profit for low-growth industry positive/break-even or negative (%)	Profit for high-growth industry positive/ break-even or negative (%)
Use of natural resources	55.0	57.2***
(n = 358, 126)	67.4	39.5
Solid waste generation	59.3	48.2
(n = 349, 129)	60.4	46.1
Wastewater effluent	52.6	44.4
(n = 355, 121)	62.2	40.0
Local or regional air pollution	42.7	32.5
(n = 267, 110)	50.0	36.1
Global pollutants	35.7	31.6***
(n = 214, 95)	43.6	19.2

Notes:
⁺ Low-growth facilities are in electronics (ISIC 31). High-growth facilities are in food products (ISIC 15).
† Top values represent facilities within the sector that earned positive profits during the past three years and that indicated they had reduced their environmental impacts. Bottom values represent facilities within the sector that had did not accrue positive during the past three years and that reported reduced environmental impacts.
* Statistically significant at $p \leq 0.10$; ** Statistically significant at $p \leq 0.05$; *** Statistically significant at $p \leq 0.01$.

change in the value of their shipments. Companies operating in sectors with the largest weighted score in the change in the value of their shipments (food) were considered 'high-growth' industries, whereas companies operating in sectors with the lowest change in the value of their shipments (electronics) were considered 'low-growth' industries.[5]

Our results showed that companies operating in high-growth sectors that earned positive profits reduced their environmental impacts upon natural resources and global pollutants more than companies in this same sector that did not earn positive profits (see Table 6.10). However, there were no statistical differences among low-growth and high-growth sectors and whether or not they reduced their solid waste, wastewater effluent, and local or regional air pollution.

In sum, compared to our prior two sector comparisons, associations between environmental improvements and facilities' financial performance

Table 6.11 Increased profits and environmental actions among different industrial sectors

Comparison group	Earned positive profits associated with reduced impacts to the environment
Facilities operating in clean versus dirty sectors	No significant differences
Early versus late movers operating in dirty sectors	No significant differences
Facilities operating in low- versus high-growth industries	Modest differences: High-growth sector that accrued positive profits reduced their use of natural resources and global pollutants more than companies in the same sector that did not accrue positive profits.

existed, but were modest. Additionally, unlike the comparison among clean and dirty sectors and early and late movers, differences did exist among companies operating in high-growth sectors. That is, high-growth sector facilities that accrued positive profits reduced their environmental impacts upon natural resources and global pollutants more than facilities in this same sector that did not accrue positive profits. Our findings therefore support the arguments put forward by Russo and Fouts (1997) suggesting that facilities in high-growth sectors are more likely to derive positive financial benefits from their environmental actions.

The results of all our sector analysis are summarized in Table 6.11. Overall, they indicate that facilities did not derive financial benefits as a result of reductions in their environmental impacts. In high-growth sectors there were some modest differences. More specifically, facilities operating in high-growth sectors that accrued positive profits were able to reduce their use of natural resources and global pollutants more than companies operating in the same sector that did not accrue positive profits. However, it is important to note that there are likely to be differences among companies within each of the sectors we compare. For example, facilities operating in clean sectors have a range of environmental performance, as do facilities operating in dirty sectors. By aggregating the facilities, and evaluating environmental performance at one point in time, we cannot account for these distinctions. Such differences may create the appearance that cleaner facilities within cleaner sectors do not benefit financially. For this reason, in addition to drawing comparisons across different sectors, future research should study the extent to which companies differ within the same sectors over time.

VIII. DISCUSSION

This study takes an important step in evaluating the relationship between a company's environmental and financial performance by studying manufacturing facilities operating in seven different countries, and by controlling for specification problems ignored in most prior studies. The results contribute to a growing body of work indicating that higher levels of environmental performance lead to greater financial returns (Khanna and Damon 1999; Hart and Ahuja 1996; Klassen and McLaughlin 1996; Konar and Cohen 1997; Russo and Fouts 1997; Rivera 2002). More specifically, this study showed that facilities that reduced their environmental impacts also demonstrated a greater probability of earning positive profits. A facility's improved environmental performance was also related to an increased probability of improving the value of its shipments.

By contrast, the stringency of the environmental policy regime was associated with a reduction in companies' financial opportunities. These findings offer evidence for the traditional economic view that the current regulatory requirements constrain an organization's financial opportunities (Friedman 1970; Christiansen and Haveman 1981; Conrad and Morrison 1989; Denison 1979; Jaffe and Palmer 1997; Lave 1973; Norsworthy et al. 1979). However, for the facilities in this study, these financial constraints were mitigated at least partially if the facility took steps to reduce its impacts upon the natural environment. Pressure from regulators was strongly related to reductions in environmental impacts. As such, it appears that regulatory pressures are critical to achieving greater environmental improvements, and that while the stringency of the regulatory regime comes at a cost to the organization, these costs may be offset if the facility improves its environmental performance. With respect to facilities' value of sales, the reported stringency of environmental policies had only a marginal effect. Our findings are illustrated in Figure 6.1.

For managers who are considering improving their facility's environmental performance, our findings provide important information that may help them gain organizational support for implementing or expanding its proactive environmental strategy. Such strategies may translate into improved public image and reputation and greater market share because these companies are in a position to market themselves as environmentally friendly organizations (Russo and Fouts 1997). Moreover, companies that improve their environmental performance faster than their competitors may also enjoy the advantages of being first-movers, and have an opportunity to receive greater purchasing preference than less environmentally conscious companies, thus fortifying their market positions (Darnall et al. 2002).

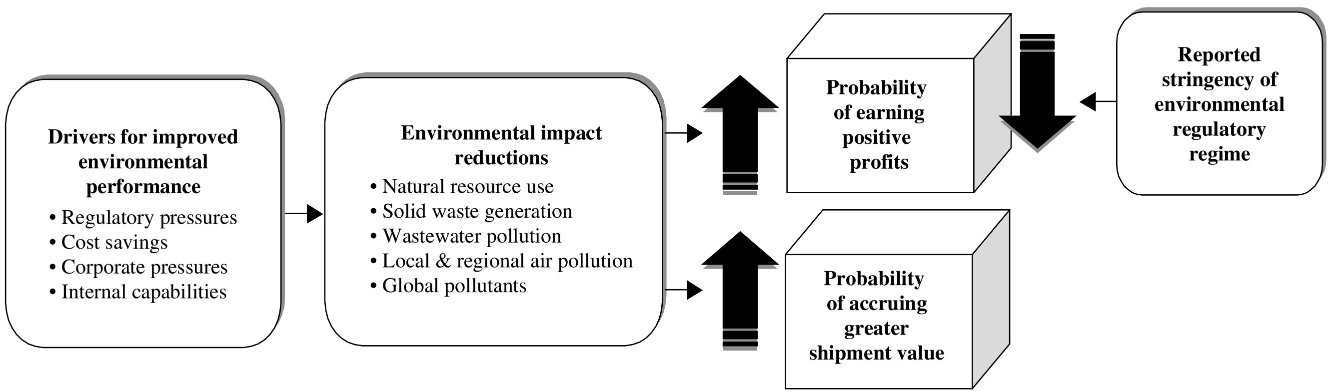

Figure 6.1 Drivers, environmental performance and probabilities for improved business performance

Our findings further suggest that organizations which seek to improve their environmental performance are not necessarily acting against conventional economic wisdom (Porter and van der Linde 1995). Instead, facilities in the seven countries we evaluated appear to be reducing their environmental impacts and benefit substantially by increasing resource productivity and cost savings. By improving their environmental performance, these companies may be marketing their environmental actions as selling points for their products, and as means to differentiate their products from the competition (Darnall et al. 2002). Doing so also helps increase their recognition for being an environmental leader, which may explain why these companies benefit from more opportunities to earn positive profits and increase the value of their sales.

With respect to our sector analyses, facilities that operated in dirty and clean sectors, and in early-mover and later-mover sectors, did not differ in whether or not they earned positive profits from their improved environmental performance. High-growth sectors that accrued positive profits had more often reduced their use of natural resources and global pollutants than facilities in the same sector that did not accrue positive profits. However, these differences were modest, and for this reason, our overall conclusion therefore is that, based on the facilities in this sample, there is little empirical support to suggest that there are differences among industry sectors. These results are further corroborated by the lack of statistical significance found in our bivariate probit regression models.

Limitations and Future Research

There are a number of limitations to our research design. First, our data were obtained using self-reported information rather than secondary sources. Traditional studies evaluating environmental performance have generally relied on the US Toxic Release Inventory (TRI), because these data are widely available. However, international comparisons of facility-level environmental performance using these data are not possible because TRI data are not collected in all countries. Rather, environmental ministries use different metrics and indicators to assess environmental performance, which makes cross-country comparisons a challenge. Similarly, prior studies that evaluate the relationship between environmental strategy and business performance have relied on stock performance, pricing, sales, intangible assets, and return on sales, equity, investment and assets. However, these data are available only for publicly traded firms and therefore a facility-level study of both publicly traded and privately owned enterprises is not possible. By focusing on a broader population of organizations, we have sacrificed greater specificity in our analysis. Such a sacrifice, however, also strengthens our work because our results have broader applicability.

Second, because our data are for a panel of companies at a single point in time, it is difficult to assess the predictive link between our variables of interest. For example, the results showed a statistically significant relationship existed between a company's improved environmental performance and financial performance. However, we cannot determine whether a company's improved environmental performance occurred prior to or after its improved financial performance. Rather, our findings show strong associations among our variables of interest. Future research would benefit from data that were collected longitudinally. Time series panel data would allow us to compare facility responses over multiple periods and determine the temporal ordering of specific events. Such information would offer more rigorous evidence for the relationships identified in this study.

A third limitation of this research is that our self-reported data may be biased in that environmental managers may have misrepresented their facility's environmental impacts and business performance. From the onset of creating its survey, the OECD believed that respondents would consist of facilities with more ambitious environmental strategies. It further believed that respondents would want to describe their environmental strategies as being more rigorous than they actually were.[6] While our results suggest that facility managers were not reluctant to identify the shortcomings of their environmental and financial performance, the potential bias would tend to reduce the variance in our sample. As such, we would be less likely to find statistically significant relationships. However, by finding statistically significant relationships, additional evidence is offered about the strength of the relationship between the variables in our models (Hardin and Hilbe 2001).

One way to increase the rigour of this research would be to compare the cross-country results of this study with the results of country-specific analyses that draw on data from other sources. For example, in estimating a facility's financial performance, country-specific publicly available financial data could be gathered to supplement the OECD database. Similarly, combining the data used in this study with publicly available data related to facilities' environmental violations and fines, and toxic environmental releases, would provide a more complete view of a company's environmental performance. These additional data would allow for analyses that would assess the specific types of regulatory approaches (for example penalties, fines and information-based policies) that increase the probability that an organization will reduce its impacts upon the natural environment and benefit financially. Since the same type of data are not collected in every country, they cannot be combined in a cross-country study.

However, more in-depth country-specific studies could help corroborate the results of this study.

IX. CONCLUSION

There is still much to learn about the relationship between environmental regulations, facilities' environmental performance, and the impact both factors have on an organization's financial performance. This study offers evidence of the robustness of these relationships even after controlling for the endogenous nature of a facility's environmental performance. It also represents the first study to consider these issues empirically across multiple international settings. The findings of our research are useful to policy makers, managers and researchers alike in helping them understand the potential benefits facilities can accrue by undertaking ambitious environmental strategies.

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G. Jason Jolley performed countless statistical computations, co-authored (with Nicole Darnall) the empirical evidence section of the literature review and assisted with editing the chapter. Haakon Flaaten helped perform the statistical computations for the sector-level analysis and assisted in administering the research workshop at BI Norwegian School of Management. Bjarne Ytterhus directed the sector-level evaluations and authored the sections associated with this analysis. He also organized and led the BI Norwegian School of Management environmental-financial performance workshop. Nicole Darnall authored remaining sections of the chapter.

Everyone who was involved in this study deserves a share of the praise. However, the authors accept responsibility for the ideas and recommendations that are presented. They also accept responsibility for any errors or omissions.

NOTES

1. Almost all environmental data suffer from some type of self-reporting bias. Even environmental compliance data and Toxic Release Inventory data are self-reported and can be misrepresented. The only type of environmental data immune from self-reporting bias is that collected by inspectors.
2. 33/50 chemicals represent the 17 most toxic chemicals in the US that are released to the environment. Companies participating in the programme were required to reduce their emissions of 17 TRI pollutants by 33 per cent by 1992 and achieve 50 per cent reductions by 1995 (Davies et al. 1996).
3. Cronbach's alpha ranges between 0 and 1. When alpha is 0.8 or over, the set of indicators is often deemed sufficiently reliable for confirmatory research. Alpha scores of between 0.6 and 0.8 are sufficient for newly developed measures (Nunnally 1978).
4. While relying on a classification of manufacturing companies in OECD countries would have been more appropriate, such a classification did not exist.
5. Given that the survey was implemented in 2003 and thus covers the period after the speculative bubble in the ITC sector had burst, results in this area need to be treated with caution.
6. As noted earlier, an often overlooked point is that TRI data, as well as most compliance data, are self-reported, and are therefore subject to the same manipulation as data obtained from surveys.

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APPENDIX 6A

Table 6A.1 Relationship between facilities' positive profits and reductions in environmental impacts

Variable	Decrease in overall impacts		Decrease in use of natural resources	
	Coeffic.	S.E.	Coeffic.	S.E.
Environmental performance (see column heading)	0.219***	0.056	0.867***	0.290
Stringency of environmental policy	−0.141**	0.060	−0.116***	0.043
Mkt. concentration is <5 competitors	0.289***	0.094	0.214***	0.069
Mkt. concentration is b/t 5–10 competitors	0.027	0.084	0.096*	0.060
Number of employees in the firm	1.7e−05***	7.0e−06	1.3e−05***	5.3e−06
Customer = end of supply chain	0.465***	0.170	0.194*	0.119
Customer = middle of supply chain	0.322**	0.164	0.125	0.116
Market scope = local	−0.413***	0.162	−0.206*	0.114
Market scope = national	−0.054	0.092	−0.055	0.066
Market scope = neighbouring counties	−0.100	0.126	−0.102	0.087
Firm is traded on stock market	0.153*	0.092	0.071	0.073
Firm's head office is in a foreign country	0.070	0.111	0.077	0.080
Food, beverage and tobacco (15–16)	0.413	0.332	0.179	0.239
Textiles, leather and footwear (17–19)	0.155	0.357	−0.267	0.260
Pulp, paper, publishing and printing (20–22)	0.254	0.330	−0.029	0.242
Chemical, rubber, plastics and fuel (23–25)	0.418	0.323	0.185	0.238
Basic metal and fabricated products (27–28)	0.535	0.355	0.158	0.260
Machinery and equipment (29–33)	0.331	0.322	0.048	0.234
Transportation equipment (34–35)	0.173	0.321	−0.134	0.233
Furniture (36)	0.298	0.344	0.078	0.248
Recycling (37)	0.440	0.414	0.013	0.294
Canada	0.253	0.178	0.329**	0.139
France	−0.193	0.165	−0.233*	0.127
Germany	0.114	0.131	−0.114	0.098
Hungary	0.414***	0.167	0.210*	0.124
Japan	−0.599***	0.124	−0.676***	0.102
Norway	0.026	0.158	−0.069	0.123
Constant	−0.083	0.393	−0.029	0.315
Observations	1390		2362	
Wald Chi2(48)	303.76***		489.01***	
Rho	−0.165		−0.487	
Wald test of rho=0 Chi2(1)	5.295***		4.589**	

Notes:
* Statistically significant at $p \leq 0.10$; ** Statistically significant at $p \leq 0.05$; *** Statistically significant at $p \leq 0.01$

Environmental performance model							
Decrease in solid waste		Decrease in waste-water effluent		Decrease in air pollution		Decrease in global pollutants	
Coeffic.	S.E.	Coeffic.	S.E.	Coeffic.	S.E.	Coeffic.	S.E.
0.907***	0.358	1.238***	0.198	1.200***	0.266	0.926***	0.219
−0.106***	0.041	−0.130***	0.038	−0.117***	0.043	−0.120**	0.054
0.224***	0.069	0.187***	0.065	0.221***	0.070	0.278***	0.084
0.093	0.059	0.071	0.054	0.045	0.058	0.073	0.073
1.3e−05***	5.5e−06	1.5e−05***	5.6e−06	1.3e−05***	5.3e−06	1.3e−05***	5.6e−06
0.172	0.120	0.186	0.110	0.264**	0.125	0.314**	0.146
0.120	0.116	0.138	0.106	0.180	0.119	0.204	0.140
−0.169	0.113	−0.203	0.108	−0.191*	0.114	−0.383***	0.143
−0.034	0.065	−0.008	0.058	−0.023	0.062	−0.028	0.079
−0.099	0.087	−0.141*	0.078	−0.119	0.086	−0.098	0.112
0.045	0.072	0.014	0.063	0.040	0.070	0.076	0.082
0.081	0.079	0.099	0.071	0.113	0.078	0.055	0.096
0.338	0.240	0.159	0.234	0.088	0.240	0.293	0.275
−0.028	0.256	−0.152	0.259	−0.157	0.265	0.013	0.304
0.125	0.236	−0.027	0.235	−0.108	0.243	0.020	0.276
0.298	0.230	0.218	0.230	0.070	0.236	0.234	0.267
0.308	0.257	0.117	0.254	−0.026	0.259	0.438	0.299
0.184	0.231	−0.004	0.227	−0.107	0.234	0.109	0.266
0.036	0.231	−0.031	0.225	−0.135	0.237	−0.083	0.264
0.199	0.243	0.107	0.242	−0.006	0.250	0.047	0.285
0.143	0.288	0.231	0.294	−0.288	0.295	0.131	0.346
0.307**	0.142	0.152*	0.144	0.439***	0.145	0.344**	0.167
−0.064	0.127	−0.198	0.119	0.139	0.147	−0.127	0.153
0.011	0.098	0.049	0.095	0.082	0.099	0.036	0.125
0.232*	0.121	0.336***	0.116	0.249**	0.119	0.381***	0.150
−0.664***	0.103	−0.408***	0.134	−0.387***	0.144	−0.589***	0.113
−0.114	0.129	0.044	0.117	0.227	0.142	0.082	0.146
−0.280	0.375	−0.279	0.286	−0.249	0.325	−0.124	0.337
2188		2389		1939		1570	
848.20***		506.07***		677.12***		400.60***	
−0.774		−0.511		−0.743		−0.507	
8.591***		3.117*		5.242**		8.534***	

Table 6A.2 Relationship between facilities' positive shipment values and reductions in environmental impacts

	Decrease in overall impacts		Decrease in use of natural resources	
Variable	Coeffic.	S.E.	Coeffic.	S.E.
Environmental performance (see column heading)	0.088	0.058	0.729***	0.279
Stringency of environmental policy	−0.029	0.061	−0.072*	0.043
Mkt. concentration is < 5 competitors	−0.065	0.094	0.008	0.066
Mkt. concentration is b/t 5–10 competitors	−0.096	0.084	−0.034	0.059
Number of employees in the firm	2.8e−08***	7.7e−06	2.2e−08***	7.0e−09
Customer = end of supply chain	−0.140	0.169	−0.101	0.119
Customer = middle of supply chain	−0.231	0.163	−0.178	0.117
Market scope = local	−0.419**	0.172	−0.421***	0.123
Market scope = national	−0.162*	0.092	−0.177***	0.068
Market scope = neighbouring counties	0.079	0.119	−0.132	0.083
Firm is traded on stock market	−0.035	0.090	−0.101	0.068
Firm's head office is in a foreign country	−0.109	0.104	−0.084	0.075
Food, beverage and tobacco (15–16)	0.097	0.337	0.078	0.237
Textiles, leather and footwear (17–19)	−0.208	0.368	−0.477*	0.265
Pulp, paper, publishing and printing (20–22)	−0.215	0.337	−0.247	0.239
Chemical, rubber, plastics and fuel (23–25)	−0.007	0.329	−0.038	0.233
Basic metal and fabricated products (27–28)	−0.336	0.357	−0.175	0.257
Machinery and equipment (29–33)	−0.173	0.329	−0.163	0.232
Transportation equipment (34–35)	−0.106	0.329	−0.226	0.232
Furniture (36)	0.103	0.347	−0.012	0.245
Recycling (37)	−0.462	0.423	−0.472	0.302
Canada	0.426***	0.155	0.536***	0.123
France	0.449***	0.166	0.416***	0.131
Germany	0.109	0.124	0.146	0.098
Hungary	0.608***	0.151	0.379***	0.118
Japan	−0.234*	0.125	−0.293***	0.097
Norway	0.224	0.159	0.124	0.120
Constant	0.088	0.058	−0.261	0.302
Observations	1396		2379	
Wald Chi2(48)	223.24***		382.23***	
Rho	−0.112		−0.493	
Wald test of rho=0 Chi2(1)	2.444		5.186**	

Notes:
* Statistically significant at $p \leq 0.10$; ** Statistically significant at $p \leq 0.05$; *** Statistically significant at $p \leq 0.01$.

Environmental performance model							
Decrease in solid waste		Decrease in waste-water effluent		Decrease in air pollution		Decrease in global pollutants	
Coeffic.	S.E.	Coeffic.	S.E.	Coeffic.	S.E.	Coeffic.	S.E.
0.669***	0.234	0.741**	0.309	0.739***	0.290	1.007***	0.276
−0.044	0.042	−0.037	0.046	−0.076	0.051	−0.077	0.056
0.010	0.066	0.034	0.070	−0.014	0.075	−0.048	0.083
−0.021	0.059	−0.022	0.062	−0.046	0.068	−0.081	0.073
2.3e−08***	7.2e−09	2.4e−08***	7.3e−09	2.3e−08***	7.1e−09	2.3e−08***	6.9e−09
−0.147	0.120	−0.049	0.130	−0.103	0.142	−0.135	0.144
−0.216*	0.117	−0.134	0.127	−0.210	0.138	−0.226	0.141
−0.459***	0.122	−0.370***	0.127	−0.484***	0.143	−0.404***	0.149
−0.182***	0.067	−0.143**	0.070	−0.170**	0.074	−0.183**	0.080
−0.126	0.084	−0.121	0.089	−0.138	0.097	−0.018	0.105
−0.090	0.068	−0.094	0.071	−0.092	0.075	−0.124	0.079
−0.082	0.075	−0.088	0.078	−0.087	0.083	−0.075	0.090
0.156	0.224	0.092	0.239	−0.040	0.264	0.219	0.314
−0.373	0.250	−0.366	0.266	−0.445	0.294	−0.098	0.338
−0.189	0.223	−0.217	0.242	−0.288	0.266	−0.150	0.316
0.010	0.215	0.048	0.235	−0.054	0.257	0.092	0.305
−0.135	0.243	−0.202	0.259	−0.318	0.284	−0.142	0.334
−0.128	0.217	−0.171	0.234	−0.208	0.257	−0.115	0.306
−0.150	0.216	−0.101	0.232	−0.192	0.257	−0.087	0.305
0.026	0.228	0.124	0.247	0.028	0.270	0.051	0.320
−0.332	0.280	−0.248	0.311	−0.433	0.321	−0.568	0.388
0.540***	0.125	0.473***	0.143	0.671***	0.135	0.426***	0.148
0.479***	0.123	0.400***	0.131	0.639***	0.142	0.458***	0.153
0.240***	0.093	0.264***	0.096	0.295***	0.101	0.007	0.121
0.424***	0.114	0.495***	0.118	0.489***	0.120	0.544***	0.143
−0.256***	0.099	−0.125	0.112	−0.158	0.111	−0.285**	0.115
0.097	0.124	0.261**	0.124	0.380***	0.139	0.211	0.149
−0.371	0.305	−0.515*	0.306	−0.266	0.335	−0.246	0.365
2406		2202		1947		1575	
376.14***		367.95***		335.88***		326.33***	
−0.483		−0.449		−0.398		−0.522	
7.376***		3.854**		3.716**		5.576***	

Table 6A.3 Determinants of improved environmental performance first stage estimation of profit model

	Decrease in overall impacts		Decrease in use of natural resources	
Variable	Coeffic.	S.E.	Coeffic.	S.E.
Regulatory influences (factor analysis)	0.102***	0.046	0.059*	0.033
Cost savings of environmental practices	0.164***	0.060	0.119**	0.056
Influence of corporate headquarters	0.195***	0.059	0.126***	0.043
Facility has budget for environmental R&D	0.203*	0.110	0.206**	0.086
Person in charge of environmental affairs	0.444***	0.098	0.381***	0.066
Number of employees in the facility	1.2e−04**	5.2e−05	1.2e−04***	4.3e−05
Food, beverage and tobacco (15–16)	0.167	0.321	0.119	0.230
Textiles, leather and footwear (17–19)	0.279	0.352	0.296	0.255
Pulp, paper, publishing and printing (20–22)	0.221	0.319	0.191	0.233
Chemical, rubber, plastics and fuel (23–25)	0.180	0.313	0.171	0.226
Basic metal and fabricated products (27–28)	0.251	0.340	0.005	0.254
Machinery and equipment (29–33)	0.163	0.312	0.078	0.226
Transportation equipment (34–35)	0.236	0.312	0.196	0.224
Furniture (36)	−0.212	0.331	0.039	0.239
Recycling (37)	0.538	0.381	0.312	0.280
Canada	−0.044	0.150	−0.065	0.125
France	−0.030	0.163	0.235**	0.127
Germany	0.238*	0.127	0.374***	0.096
Hungary	−0.229	0.144	0.099	0.110
Japan	0.081	0.112	0.240***	0.094
Norway	−0.168	0.157	0.244**	0.124
Constant	−1.529***	0.373	−1.182***	0.297
Observations	1390		2362	
Wald Chi2(48)	303.76***		489.01***	
Rho	−0.165		−0.487	
Wald test of rho=0 Chi2(1)	5.295***		4.589**	

Notes:
* Statistically significant at $p \leq 0.10$; ** Statistically significant at $p \leq 0.05$; *** Statistically significant at $p \leq 0.01$.

Environmental performance model							
Decrease in solid waste		Decrease in wastewater effluent		Decrease in air pollution		Decrease in global pollutants	
Coeffic.	S.E.	Coeffic.	S.E.	Coeffic.	S.E.	Coeffic.	S.E.
0.008	0.033	0.097***	0.034	0.116***	0.038	0.115***	0.043
0.108*	0.061	0.062	0.049	0.008	0.046	0.067	0.056
0.144***	0.043	0.052	0.040	0.151***	0.054	0.224***	0.056
0.336***	0.090	0.150**	0.078	0.212**	0.087	0.246***	0.099
0.295***	0.067	0.353***	0.068	0.218***	0.072	0.393***	0.094
1.4e−04***	3.7e−05	1.9e−04***	4.9e−05	1.5e−04***	3.9e−05	1.5e−04***	4.4e−05
−0.497**	0.234	0.278	0.246	−0.001	0.242	−0.215	0.291
−0.218	0.256	0.323	0.272	0.034	0.273	−0.005	0.329
−0.210	0.236	0.309	0.249	0.026	0.244	−0.021	0.292
−0.207	0.231	0.152	0.242	−0.001	0.237	−0.134	0.283
−0.397	0.256	0.214	0.268	−0.061	0.265	−0.203	0.315
−0.341	0.229	0.266	0.241	0.005	0.236	−0.073	0.282
−0.332	0.228	0.095	0.240	−0.172	0.235	0.010	0.281
−0.315	0.243	0.015	0.257	−0.200	0.251	−0.032	0.300
0.004	0.285	−0.104	0.303	0.492*	0.298	0.429	0.343
0.099	0.125	0.155	0.133	−0.216*	0.132	0.104	0.149
−0.095	0.124	0.182	0.127	−0.326**	0.140	0.037	0.160
0.064	0.096	0.029	0.101	0.060	0.106	0.563***	0.121
−0.010	0.110	−0.331***	0.113	−0.092	0.114	−0.030	0.141
0.220**	0.094	−0.199**	0.097	−0.093	0.101	0.378***	0.109
0.446***	0.128	0.015	0.125	−0.270**	0.137	0.072	0.156
−0.549*	0.314	−0.880***	0.303	−0.695***	0.311	−1.694***	0.351
2188		2389		1939		1570	
848.20***		506.07***		677.12***		400.60***	
−0.774		−0.511		−0.743		−0.507	
8.591***		3.117*		5.242**		8.534***	

Table 6A.4 Determinants of improved environmental performance first stage estimation of value of shipments model

	Decrease in overall impacts		Decrease in use of natural resources	
Variable	Coeffic.	S.E.	Coeffic.	S.E.
Regulatory influences (factor analysis)	0.103**	0.046	0.058*	0.033
Cost savings of environmental practices	0.169***	0.060	0.142***	0.048
Influence of corporate headquarters	0.196***	0.059	0.143***	0.043
Facility has budget for environmental R&D	0.224**	0.108	0.236***	0.084
Person in charge of environmental affairs	0.415***	0.098	0.330***	0.068
Number of employees in the facility	1.2e−04**	5.3e−05	1.1e−04**	4.6e−05
Food, beverage and tobacco (15–16)	0.131	0.321	0.089	0.229
Textiles, leather and footwear (17–19)	0.267	0.353	0.284	0.254
Pulp, paper, publishing and printing (20–22)	0.208	0.320	0.204	0.231
Chemical, rubber, plastics and fuel (23–25)	0.177	0.314	0.184	0.225
Basic metal and fabricated products (27–28)	0.267	0.340	0.018	0.251
Machinery and equipment (29–33)	0.176	0.313	0.097	0.224
Transportation equipment (34–35)	0.223	0.312	0.192	0.223
Furniture (36)	−0.185	0.332	0.081	0.237
Recycling (37)	0.515	0.383	0.287	0.285
Canada	−0.064	0.149	−0.089	0.124
France	−0.054	0.164	0.214*	0.127
Germany	0.240*	0.127	0.383***	0.096
Hungary	−0.248*	0.143	0.091	0.109
Japan	0.064	0.113	0.235***	0.094
Norway	−0.171	0.157	0.245**	0.123
Constant	−1.512***	0.376	−1.243***	0.281
Observations	1396		2379	
Wald Chi2(48)	223.24***		382.23***	
Rho	−0.112		−0.493	
Wald test of rho=0 Chi2(1)	2.444		5.186**	

Notes:
* Statistically significant at $p \leq 0.10$; ** Statistically significant at $p \leq 0.05$; *** Statistically significant at $p \leq 0.01$.

Environmental performance model

Decrease in solid waste		Decrease in waste-water effluent		Decrease in air pollution		Decrease in global pollutants	
Coeffic.	S.E.	Coeffic.	S.E.	Coeffic.	S.E.	Coeffic.	S.E.
0.011	0.033	0.115***	0.037	0.126***	0.040	0.117***	0.043
0.142***	0.047	0.094*	0.050	0.041	0.050	0.092*	0.054
0.175***	0.042	0.062	0.047	0.183***	0.049	0.213***	0.055
0.384***	0.086	0.171**	0.086	0.243***	0.092	0.296***	0.094
0.240***	0.066	0.325***	0.073	0.171**	0.080	0.360***	0.096
1.8e−04***	5.1e−05	1.0e−04**	4.2e−05	1.3e−04***	4.2e−05	1.3e−04***	4.5e−05
−0.478**	0.224	0.287	0.239	0.032	0.250	−0.196	0.312
−0.185	0.245	0.373	0.263	0.069	0.279	0.035	0.347
−0.187	0.225	0.359	0.241	0.060	0.251	0.009	0.311
−0.157	0.219	0.180	0.235	0.051	0.243	−0.079	0.304
−0.301	0.243	0.232	0.261	0.006	0.270	−0.130	0.334
−0.288	0.218	0.323	0.233	0.055	0.243	−0.025	0.304
−0.286	0.216	0.159	0.233	−0.093	0.241	0.054	0.302
−0.253	0.231	0.133	0.248	−0.121	0.257	0.027	0.320
−0.006	0.280	−0.068	0.303	0.595**	0.301	0.502	0.366
0.080	0.124	0.158	0.133	−0.262**	0.131	0.116	0.147
−0.103	0.125	0.182	0.129	−0.331***	0.139	0.045	0.161
0.064	0.095	0.058	0.099	0.074	0.104	0.587***	0.120
−0.028	0.110	−0.336***	0.113	−0.122	0.113	−0.026	0.141
0.227**	0.094	−0.174*	0.096	−0.096	0.099	0.347***	0.109
0.480***	0.126	0.044	0.126	−0.278**	0.137	0.051	0.157
−0.708***	0.272	−1.014***	0.287	−0.852***	0.299	−1.732***	0.365
2406		2202		1947		1575	
376.14***		367.95***		335.88***		326.33***	
−0.483		−0.449		−0.398		−0.522	
7.376***		3.854**		3.716**		5.576***	

7. Environmental policy and corporate behaviour: policy conclusions

Nick Johnstone

Assessment of the effectiveness of public environmental policy measures is dependent upon a good understanding of environmental management, investment and performance within firms and facilities. This book reports on the results of a three-year project coordinated by the OECD Environment Directorate and including over 20 researchers which has sought to assess public policy initiatives through the application of econometric techniques to a database of manufacturing facilities in seven OECD countries (Japan, France, Germany, Norway, Hungary, Canada and the United States).

The data were collected via a postal survey, eliciting information on firm and facility characteristics (sector, size, market, and so on), environmental management systems, tools and practices, environmental investments, performance and innovation, and the public policy framework. The analysis of the results of a survey applying the same questionnaire across a wide spectrum of facilities (size, sector, country, and so on) is one of the significant contributions of the project.

There are, however, some weaknesses inherent in such an approach. Firstly, the use of a survey instrument to which responses are voluntary introduces potential bias in the sample, with weak environmental performers being under-represented. Secondly, those facilities that do respond may do so strategically, believing that their responses may have implications for future policy developments. Thirdly, since the data collected are a single cross-section, the dynamic relationships between different variables are difficult to assess. And finally, in order to ensure adequate response rates much of the data are qualitative in nature since respondents are unlikely to be able to provide quantitative responses for many issues of interest.

Recognizing these limitations, however, the database is a unique and valuable source of information on the links between public environmental policy and corporate behaviour. It is hoped that the results of the work will provide insights into the design of effective and efficient environmental policy, taking into account the heterogeneity of firms' characteristics.

Insights have been gathered on the determinants of environmental management, environmental performance, innovation (cleaner production and research and development), and commercial–environmental linkages.

In the work undertaken by Henriques and Sadorsky (Chapter 2), environmental management is characterized broadly, extending well beyond the simple indicator of whether or not a facility has an environmental management system in place or not. For instance, a distinction is drawn between facilities which merely report having environmental management systems in place and those which have had them certified, where certification can be considered as a form of third-party assessment of the quality of the EMS. In addition, drawing upon the database's rich characterization of environmental management tools (environmental accounting, reporting, auditing, training, and so on) the comprehensiveness of the environmental management framework can be measured. And finally, the presence of an individual with explicit designated responsibility for environmental matters is also taken as an indicator of the quality of environmental management.

Results of the estimations undertaken reveal that the general role of public authorities with respect to the decision to improve environmental management is insignificant, with employees, corporate headquarters and downstream buyers being more influential. However, the frequency of inspections (regulatory oversight) has a positive effect on the designation of an individual as being responsible for environmental matters and on the comprehensiveness of environmental management. In addition, the provision of direct incentives for the introduction of environmental management has a positive influence in all models estimated, except the decision to certify an EMS. Separate work undertaken by Johnstone et al. (Chapter 3) indicates that of the targeted incentives for the introduction of environmental management, perceived reduced inspection frequency and financial assistance are the most important. For small and medium-sized enterprises the provision of information also has a positive effect.

In terms of general environmental policy instruments, the provision of technical assistance has a consistently negative impact on the implementation of environmental management. This somewhat surprising result might be explained by potential substitution that might exist between internal management practices and the publicly provided technical assistance. Despite the robustness of the result this is clearly an area which requires further examination. Voluntary agreements have a positive influence on environmental management, but there is some concern that certain respondents may perceive environmental management systems *per se* as a voluntary environmental policy measure.

With respect to the other determinants of environmental management, the factors which emerged consistently as being statistically significant in at least two of the econometric models estimated include: international scope of markets; facility size in terms of number of employees; reported profitability of the facility; presence of other more general management tools such as quality management systems; public listing on a stock exchange; and industrial sector of the facility's primary output.

Self-reported assessment of the determinants of reported environmental investments undertaken and changes in environmental performance are likely to be particularly affected by potential response and strategic bias. However, there was considerable variation in the data. Variation in the data allowed for the analysis of both direct and indirect policy influences on environmental actions and performance, with a focus on air and water pollution and solid waste generation. Direct policy measures would include standard environmental policy measures targeted directly at environmental performance or some proxy (technology standards, performance standards, market-based measures, and so on), while indirect policy measures are incentives provided for environmental management.

Results of this work indicate that perceived policy stringency and (to a somewhat lesser extent) inspection frequency have a positive and significant impact on environmental performance. This result is hardly surprising. Conversely, instrument choice did not seem to matter, although the presence of performance standards frequently emerged as having a positive role. Surprisingly, input taxes occasionally had a negative effect. However, this is perhaps explained by the fact that when they are introduced they are often set at very low levels, a distinction which may not be fully captured by the inclusion of the variable for policy stringency as a control.

The results also indicate that environmental management matters for environmental actions and performance, both in terms of the implementation of an environmental management system and with respect to the explicit designation of somebody as being responsible for environmental matters within the facility. Moreover, for those facilities that have implemented environmental management systems there is some support for the positive role played by third-party certification and the length of time in which the EMS has been in place. This reveals the importance of EMS 'quality'. Conversely, given the results noted above concerning the role of perceived reduced inspection frequency as an inducement to introduce an EMS, efforts were made to assess whether this had perverse effects, with facilities with weak environmental performance introducing EMSs to signal their good intentions to public authorities. However, the results were insignificant in this regard.

Other factors which encourage environmental investments and improved performance include the nature of competition in the market, with facilities that saw competition on the basis of product quality as being more important than price competition more likely to be environmentally proactive. Facility employment was also important, but less so when the two decisions (management and performance) were estimated simultaneously. More generally, for solid waste issues, commercial and market conditions played a more important role than for air and water pollution, where policy influences were more important.

The decision to invest in environment-related research and development is an area which has not been explored to any great extent in previous empirical work. In Chapter 4 Arimura et al. found that perceived policy stringency had a positive effect on this decision. This is consistent with the general view that the introduction of a stringent environmental policy – by changing relative prices or introducing production constraints – provides incentives to search out alternative means of improving environmental performance. In addition, environmental accounting – but not environmental management systems – have a positive influence on environmental R&D.

Since returns on research and development are likely to be greater if the potential scope for the implementation of any innovation arising is wide, flexible instruments should have more positive effects than more prescriptive instruments which constrain technological choices. No direct evidence for this is found. However, it is found that the introduction of more flexible instruments can have a positive indirect influence. In particular, they encourage the introduction of environmental accounting which in turn encourages investment in environment-related research and development. And finally, technical assistance has a positive role on the decision to invest in environment-related R&D, perhaps reflecting the complementary roles of public and private research efforts.

The decision to invest in cleaner production (or a change in production process – CPP) rather than end-of-pipe (EOP) abatement was explored by Frondel et al. (Chapter 5). Investment in a change in production process to address environmental concerns can be seen as a reflection of an ability and willingness to address abatement and production decisions in an integrated manner, perhaps allowing for the joint realization of commercial and environmental objectives. In this vein it is reassuring to see that facilities which report having invested in CPP rather than EOP cite cost savings as an important factor in their environmental strategy. Conversely, for those who invest in EOP, regulatory pressures are more important.

Thus, the presence of direct regulations (technology standards) increases the propensity to invest in EOP, while input taxes favour the introduction of CPP. In the work of Frondel et al. reported in Chapter 5 the presence of input bans also favours the introduction of CPP measures. This result is hardly surprising, since the requirements of an input ban can not be met through EOP abatement.

In addition, internal environmental management capacity seems to play a more significant role in the decision to invest in CPP, perhaps reflecting the greater technical and managerial requirements of such investments. Moreover, the location of the individual who is responsible for environmental matters also has an influence.

The final chapter by Darnall et al. (Chapter 6) examined the extent to which improved environmental performance yields commercial gains. Obviously environmental factors play a limited role in a facility's overall commercial performance, with factors such the nature of the market and product proving to be very significant. However, they do find robust evidence that good environmental performers are more likely to report being profitable and experiencing sales growth. There are 'win–wins'.

Significantly, however, they find that the role of perceived policy stringency is consistently negative – that is, if there are 'win–wins' they are not induced through regulatory stringency. As a conclusion, this is reassuring because it implies that facilities are undertaking initiatives to improve environmental performance which are in their private commercial interest (input cost savings, branding and product differentiation, reduced liabilities, and so on), and that public authorities are focusing on the measures that would not otherwise be undertaken by firms (that is, in which the benefits are primarily external to the firm).

In general, therefore, the results confirm the importance of the public policy framework on environmental management, performance and innovation. Policy stringency matters and so does inspection frequency. The results with respect to instrument choice are less evident, but there is some support for the use of more flexible instruments, particularly with respect to technological innovation. Moreover, implementation of environmental management systems and tools has a positive influence on environmental performance and innovation. However, it is less clear that the latter result has significant implications for public authorities. If incentives are to be provided for the introduction of environmental management these should be thought through carefully. The costs and benefits of the provision of indirect incentives to encourage improved environmental performance (via environmental management) need to be balanced carefully.

In addition, it is important to bear in mind that other factors (other stakeholders, market characteristics, commercial conditions, and so on) have an important influence on environmental management, performance and innovation. Assessment of environmental policy must take the heterogeneity of firm responses into account. And finally, while commercial–environmental 'win–wins' may be important, the argument that more stringent environmental policy can support such synergies is not supported. However, there is no question that depending upon instrument choice the cost implications of meeting environmental objectives is likely to vary widely.

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Appendix 2 Survey design and protocol

The survey design and protocol drew inspiration from the principles laid out in Dillman's (1978) 'Total Design Method'.

QUESTIONNAIRE DESIGN

- designed in collaboration between research teams (approximately 14 researchers) and advisory group members (single representative from each participating country);
- email correspondence and two meetings held at the OECD in 2003 and 2004 – 18 different versions discussed;
- inputs on survey design obtained from representatives of the OECD's Business and Industry Advisory Committee;
- two-way translation from English into French, Japanese, Norwegian, German and Hungarian;
- pre-tested amongst a selection of representative manufacturing facilities in Japan, Germany and Canada;
- subsequent modifications to ease completion, ensuring that survey did not exceed 12 pages in length and remained easily legible;
- sampling;
- population of manufacturing facilities with 50 or more employees in seven participating countries;
- sample derived from universal population databases (except for United States – database of TRI facilities);
- stratified sampling by industrial sector (2-digit level) and by facility size (50–99; 100–249; 250–499; >500).

DATA COLLECTION

- postal surveys mailed out to almost 17 000 manufacturing facilities on or around 7 January 2003 (see schedule below);

- additional possibility to fill in questionnaire online for United States survey (give website address);
- accompanying letter (OECD and departmental/university letterheads) addressed to chief executive officers and/or 'environmental managers';
- two postal reminders (in some cases telephone) to a selection of non-respondents within one and two months of initial mail-out to increase response rate.

Table 2A.1 Schedule for data collection

Project stages	Indicative timeframe
Completion of pre-testing by Germany, Canada, France, and Japan	16 November 2002
Final version of questionnaire agreed upon	30 November 2002
Translation of questionnaire in all languages	20 December 2002
Questionnaires posted by research teams	7 January 2003
Postal reminder 1	4 February 2003
Postal reminder 2	4 March 2003
Deadline for receipt of questionnaires from firms	8 April 2003

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Environmental Policy and Corporate Behaviour

For the last 30 years, analysis of the inner workings of the firm has been largely absent from economic assessments of environmental policy. Recent work has highlighted the importance of understanding a firm's commercial motivations, decision-making procedures and organizational structure when designing and implementing public environmental policies. *Environmental Policy and Corporate Behaviour* responds to this need, investigating the many internal challenges faced by firms seeking to implement new policies and achieve significant and long-lasting environmental progress.

The authors provide an in-depth empirical analysis of an industrial survey undertaken in seven OECD countries (Japan, France, Germany, Hungary, Norway, Canada and the United States), spanning 4000 facilities in all manufacturing sectors, including small and medium-sized enterprises. They use their findings to illustrate the links between public (government) environmental policies and private (firm and facility) environmental management, investments, innovation and performance.

With a specific focus on the public policy implications of the empirical findings, the book provides a foundation upon which to formulate public and corporate policy in the environmental sphere. Adopting a multi-disciplinary approach, the book will appeal to academics and policymakers with an interest in economics of the environment, as well as presenting business and management perspectives.

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