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Conference Objective

To present and synthesize current research regarding the hypothesis that the cost of implementing environmental regulations may be expected to be significantly reduced by low-cost process innovations carried out by regulated firms. Different perspectives on this hypothesis will be presented drawing on economics, organizational, and legal theory, together with their implications for the analysis of policy. Contributions are expected from a variety of fields and differing approaches, ranging from case studies to the statistical analysis of large date sets.

Acknowledgement and Disclaimer

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INNOVATION, COST AND REGULATION:

PERSPECTIVES ON BUSINESS, POLICY AND LEGAL FACTORS AFFECTING THE COST OF ENVIRONMENTAL COMPLIANCE

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Executive Summary

This report presents and synthesizes current research regarding the hypothesis that the cost of implementing environmental regulations may be expected to be significantly reduced by low-cost process and other innovations carried out by regulated firms. This hypothesis has been popularized by Professor Michael Porter, who argues that "properly designed environmental standards can trigger innovation that may partly or more than fully offset the costs of complying with them." The report offers various perspectives on the hypothesis, drawing from economics, organizational, and legal theory, together with the implications of such perspectives for the analysis of policy.

In addition, an appendix to the report presents the summary of a workshop held on April 30th, 1999 that brought together some of the leading researchers on the subject. Perhaps the most salient theme running through the workshop presentations was agreement on the need to adapt our environmental regulatory framework to be friendlier to innovation and pollution prevention. Recommendations varied from legal reforms that retain strict standards while allowing greater flexibility in compliance alternatives, to a greater understanding and consideration of technology options and characteristics in the regulated industry.

The Porter hypothesis is supported in part by theories of competitiveness that posit that any regulation that requires a company to re-examine its production process generates a probability of innovation in that process that may benefit overall competitiveness and reduce or even eliminate costs of compliance. In addition, a second strand to this theory adds that environmental regulation in particular may lead to improved competitiveness, as pollution represents wasted resources which could be more effectively used. Regulation which requires reduced pollution therefore inherently favors more productive processes.

However, the evidence supporting the Porter hypothesis has tended to be anecdotal. It includes case studies of various industries which reveal win-win situations, as well as reports on company programs that have documented consistent cost savings from waste reduction activities. All these examples suffer from possible selection bias, making it difficult to generalize their findings. In addition to these industry case studies, a study of U.S. states found that those with strict environmental laws have better economic performance than those with lower standards. However, that study sheds little light on causal factors, and economists have tended to dismiss is as an unsupported and possibly spurious positive correlation.

In contrast, the economics literature that measures firms' actual costs of compliance with environmental regulations shows generally that regulation has imposed positive costs, although the costs are to some degree offset by savings from innovation. This research examines plant-level data to identify any productivity penalty from pollution control expenditures, using data from the Pollution Abatement Costs and Expenditures Survey and Census of Manufactures in dynamic general equilibrium analyses. Recent work using a fixed effects model reveals that, on average, environmental regulation did occasion economic costs, but the costs were reduced 18 cents per dollar by efficiency gains in a number of industries, leaving a net cost of $.82. The costs observed in individual industries varied widely. Although some research identifies high long-run costs associated with environmental regulation, the study using a fixed effects model shows that these results may be caused by failing to account for inter-plant differences.

In an effort to move beyond the stalemate suggested by the research described above, this report examines the nature and potential of real-world legal and business barriers that may prevent industry from achieving least-cost, innovative or pollution prevention goals. This review reveals that the design of environmental regulation exerts a significant effect on the cost of compliance. Overall, many of the problems of inflexibility in our current system could be avoided by better designed regulations, including a greater effort to set overall performance standards such as mass standards. A central problem identified is that the design of discharge rate standards based on "available" or "feasible" control technologies under the Clean Water Act and Clean Air Act strongly discourage innovation. This review suggests that the legal setting may be the primary determinant as to whether businesses can innovate to reduce compliance costs.

Fundamentally, achieving the benefits suggested by the Porter hypothesis requires that environmental regulation cause a firm to re-examine its process technologies to find greater efficiencies and cleaner processes. Small changes in standards will not encourage firms to make such a review. Only standards that make significant reductions while allowing flexibility in the response adopted by industry are likely to effect innovation and change in production processes. Our current regulatory system therefore provides a highly imperfect arena in which to test the Porter hypothesis, as the design of regulations appears to have at least as great an impact on the costs of compliance as do the traditional economic forces which might lead to innovation.

Another potential source of barriers to achieving the benefits suggested by the Porter hypothesis is identified in the literature on firm behavior and management, which reveals that many aspects of firm structure and incentives do not foster innovation. Research has identified problems caused by: production staff not being responsible for environmental compliance; the treatment of environmental costs in incentive structures and in accounting systems; lack of time; imperfect communications structures; the influence of habits and routines; and industry rigidity.

In addition, real-world considerations of risk, strategy and other factors are found to create disincentives for investing in potentially attractive pollution prevention for completely legitimate business reasons. These range from small firm characteristics that preclude any consideration or development of alternative technologies, to high hurdle rates for new investment, to the lock-in effect of high-cost capital equipment that is already in place.

Although all these factors help to explain whether businesses are likely to be able to innovate in response to environmental regulation, their richness and complexity also indicates the need for greater understanding and analysis. Improvements in regulatory design, and in ways to improve management decisions like environmental management systems, offer ways to help firms achieve the win-win situations, and achieve environmental goals at low cost.

Introduction

Some authors have stated that environmental regulation, properly structured, can result in win-win situations in which production costs decline as environmental benefits rise. Professor Michael Porter, and before him Professor Nicholas Ashford, have advocated such a view as part of a broader hypothesis that posits that any pressure placed on a firm that creates greater incentives to innovate may be ultimately good, as it leads to the kinds of innovation and improvement that benefits competitiveness and profitability.

This hypothesis in some ways conflicts with traditional economic theory, which indicates that regulations imposing additional environmental requirements on industry would tend to reduce profitability and competitiveness. Indeed, much of the economic literature points to such a negative correlation between environmental regulation and costs. Another view suggests that the costs may be partly but not entirely offset by efficiency gains which are prompted by the effort to reduce pollution in response to regulation. These economic studies would infer that environmental regulation requires a careful cost-benefit assessment that weighs the social benefits of improved environmental quality with the necessary private costs to implement any regulation.

ELI is attempting to identify the circumstances and reasons that may lead to situations where process improvements and innovations due to regulation result in cost reductions or savings to private firms. In doing so we will test the real-world situation in which firms operate to identify social, legal and economic reasons that may lead to such win-win situations.

I. The Hypothesis that Environmental Regulation May Result in Lower Costs or Net Profits

Professor Michael Porter puts forth the following hypothesis:

> "This paradigm of dynamic competitiveness raises an intriguing possibility: in this paper, we will argue that properly designed environmental standards can trigger innovation that may partly or more than fully offset the costs of complying with them" (Porter 1995b at 98).

This builds upon earlier work by Nicholas Ashford and others that "health, safety and environmental goals can be co-optimized with economic growth though technological innovation" (Ashford, Ayers and Stone 1985).

These statements imply a continuum whereby the solution to some pollution problems may result in increased net costs, others may have costs reduced but not eliminated from innovation, while a third set exhibits true "win-win" characteristics with economic profits realized though innovation prompted by the regulation.

Two distinct elements support this hypothesis. The first emphasizes the role of innovation in a modern theory of dynamic competitiveness, as Porter states that "the new paradigm of international competitiveness is a dynamic one, based on innovation" (Porter 1995b at 97). This emphasis on innovation raises the benefits expected from thorough-going reassessment of production processes such as that occasioned by new and stringent environmental regulation. In this element, any pressure placed on an industry that forces firms to pay greater attention to innovation may be broadly beneficial as innovation is necessary to gain or retain market share and profitability in the modern marketplace.

According to this element the hypothesis might be recast thus: "Any regulation that requires a company to re-examine its production process generates a probability of innovation in that process that will reduce or even eliminate costs of compliance." Accordingly, the degree and design of the regulation imposed is critical. The hypothesis does not even apply unless regulation is both sufficiently stringent and flexible so that firms re-evaluate their production processes. This reveals serious problems in the environmental field, as many of our environmental regulations are designed in a way that discourages precisely such a re-examination of process technology. Instead they are designed to impose "control technologies" that are economically reasonable or achievable. In addition, they raise standards sporadically and hence create no continuous drivers for improvement, further discouraging investigation into better technologies. These regulatory barriers to achieving win-win scenarios are widespread in our laws, and as described further below, deserve far more attention than they are receiving.

The second strand adds to this concept the particular reasons why environmental regulation may lead to improved competitiveness, as pollution represents wasted resources which could be more effectively used. Porter states, "the reason [pollution control may enhance competitiveness] is that pollution often is a form of economic waste.... [P]ollution ... is a sign that resources have been used incompletely, inefficiently or ineffectively" (Porter 1995a at 122) and "efforts to reduce pollution and maximize profits share the same basic principles, including the efficient use of inputs, substitution of less expensive materials and the minimization of unneeded activities" (Porter 1995b at 106). Regulation which requires reduced pollution therefore inherently favors more productive processes. Reasons within and without the firm that may promote or prevent the achievement of win-win solutions are further described below in part III.

The evidence supporting the Porter hypothesis has tended to be anecdotal, relating to case studies of various industries that reveal win-win situations. These include vinyl chloride, (Doniger 1978), distilled spirits (ELI Forum 1993) and others (Strasser 1997; Palmer, Oates and Portney 1995; Portney 1994; Ashford 1985). One study of the chemical industry identified 181 source reduction activities, only one with a positive cost, and 2/3 of which paid themselves back in less than six months (Dorfman 1992 at 22). A six-industry study conducted by the Management Institute for Environment and Business (1996) generally found that environmental regulation did impose costs, but that many instances could be found where companies gained competitive advantage in process efficiency and product quality though innovations spurred by environmental pressures. Company programs to reduce wastes have also documented consistent cost savings from waste reduction activities. 3M reports that its Pollution Prevention Pays generated 3,000 projects preventing 575,000 tons of pollution and saving over $530 million from 1975 to 1992

(Smart 1992). However, all these examples suffer from possible selection bias, making it difficult to generalize their findings.

In addition to these industry case studies, a study by Meyers (1993) found that states with strict environmental laws have better economic performance than those with states with lower standards. However, its sheds little light on causal factors and economists have tended to dismiss is as an unsupported and possibly spurious positive correlation (Jaffee 1995 at 157).

Porter notes that: "These examples and many others like them do not prove that companies always can innovate to reduce environmental impact at low cost," but that "the opportunity to reduce costs by diminishing pollution should thus be the rule, not the exception." This is despite industry opposition to environmental regulation and the often-restrictive nature of that regulation (Porter 1995a at 127). An Office of Technology Assessment agrees that "even though an aggressive pollution prevention effort can reduce compliance costs, particularly when compared to the current end-of-pipe approach, industry still faces compliance costs that increase production costs" (OTA 1994 at 85).

A more thorough discussion of these issues is made below, starting with the economic critiques of the assertions in the Porter hypothesis, followed by an examination of policy and economic factors that may tend to reject or favor the hypothesis. Thorough treatment is given to the role of regulatory barriers to innovation, as it appears that the degree and design of regulation plays a significant role, together with more purely economic considerations, in a firm□s ability to innovate to reduce the costs of compliance.

II. Traditional economic views

A. Critiques of the Porter Hypothesis

"The conventional wisdom is that environmental regulations impose significant costs, slow productivity growth, and thereby hinder the ability of U.S. firms to compete in international markets" (Jaffee 1995 at 133; Schmalensee 1994). EPA has estimated the direct costs of environmental compliance to be $115 billion or 2.1 percent of GDP in 1990 (USEPA 1990), and some authors estimate that additional indirect costs of regulation are two to three times greater (Weitzman 1994).

Although there are several reasons why the effects of environmental regulation on competitiveness may be small and hard to define, the prevailing view asserts several reasons why environmental costs should negatively affect productivity (Jaffee 1995 at 150, 158):

a) A first argument refers to straight displacement - dollars which go to environmental quality do not go towards production. Gray and Shadbegian (1993) found a 1.5/1 ratio between environmental costs and output.

b) Second, the new practices required by environmental regulation may be less efficient than the former ones, which in theory would have been set at an optimum. One example is that of emissions controls for nitrogen oxides (NOx) which require boilers to be set at less than thermodynamically efficient combustion temperatures (Schmalensee 1993). This is directly opposed to Porter's hypothesis, which stresses efficiency gains.

c) A third argument is that the costs occasioned by environmental regulation actually have a negative multiplier effect, as environmental investment crowds out other investment which could lead to productivity gains. Hazila and Kopp (1990) found that regulation magnifies environmental cost because of restrictions in investment and labor supply. Also, Jorgensesn and Wilcoxen (1990) found the indirect cumulative effects of regulations reduce the average growth rate of GNP by 0.2%.

d) A fourth area concerns productivity losses due to unnecessary rigidity or poor design of environmental laws. These do not contradict Porter, who also emphasizes the need for innovation-friendly regulation. Although this subject is treated in more detail below, the type of regulation promulgated clearly has a major impact on whether regulation can result in economic gains, and can to some extent explains the discrepancy between the Porter hypothesis and plant-level studies showing a positive correlation between environmental regulation and economic costs.

Empirical analyses of these adverse effects have found positive economic costs from environmental regulation. A number of studies cited by the Office of Technology Assessment revealed between an 8 and 16 percent decline in productivity growth rate due to environmental regulation in the 1970s over all manufacturing sectors, and up to 44% for certain industries (OTA 1994 at 323).

Several authors have examined plant-level data to identify any "productivity penalty" from pollution control expenditures. These have used data from the Pollution Abatement Costs and Expenditures (PACE) Survey and Census of Manufactures in dynamic general equilibrium analyses to estimate the long-run consequences of environmental regulation. Hazila and Kopp (1990) found that regulation magnifies environmental cost because of restrictions in investment and labor supply. Also, Jorgensesn and Wilcoxen (1990) found the indirect cumulative effects of regulations reduce the average growth rate of GNP by 0.2%. Research by Gray and Shadbegian (1994) found a weak negative correlation, that output fell between 1 and 1.5 for every unit of pollution control expenditure depending in the model used. They found marginal cost of $1.74 for paper mills, $1.35 for oil refineries and $3.28 for steel mills, but also report lower results ($0.55, $0.97 and $2.76) for a fixed-effects model (see also Palmer and Simpson 1993).

However, recent work by Morgenstern and Pizer found that the results of these studies may depend more on the model being used:

"While we are able to replicate their general results ..., we show that those results depend critically on strong assumptions about homogeneity among plants. Specifically, they assume that differences in plant location, age and management have no effect on either productivity or environmental expenditure - an assumption that seems unlikely to be satisfied in practice. Allowing for such differences (by estimating a fixed-effects rather than a pooled model) substantially reduces the estimated economic costs associated with an incremental dollar of reported expenditures. Our results, in fact, allow us to statistically reject the hypothesis that the economic cost of an additional dollar of reported environmental expenditure is much more than one dollar." (Morgenstern 1998 at 9).

Their analysis of four heavily regulated manufacturing industries using a fixed effects model showed that on average, environmental regulation did occasion economic costs, but the costs were reduced 18 cents per dollar by efficiency gains, leaving a net cost of $.82. Individual industries varied considerably. For the plastics industry, a one dollar increase in PACE expenditures was partially offset by an 80 cent cost savings in non-environmental production costs (leaving 20 cents net costs); in pulp and paper, a 36 cent savings; in petroleum, a 2 cent savings; but in steel, a 41 cent cost increase.

At the 95 percent confidence level, the true economic cost ranges from negative 2 cents (a profit) to positive $1.68. Although findings for the four individual industries were not at the statistical significant level, they indicate the potential for environmental expenditures to induce significant cost savings, and rule out the possibility that cost increases are high. The analysis showed that using pooled estimates which de-emphasize differences between plant would have resulted in a much higher estimate of indirect effects of environmental regulation, to $2.73, and is more in line with other estimates. They suggest these higher numbers are overestimates. Their study shows that current environmental regulations result in positive costs, but that these are somewhat offset by related savings.

A second finding of the Morgenstern and other studies is the variability among sectors. This reflects both that some environmental problems are more difficult to solve than others, which Porter admits, but also the effects of regulation in the industry. The steel industry is a particularly interesting case, as several of the studies cited report unusually high environmental compliance costs for the steel industry (Morgenstern 1998, Joshi 1998, Gray and Shadbegian 1993). However, an Environmental Law Institute study of barriers to innovation in six industries also shows that the steel industry faces particularly inflexible environmental regulations, which has significant problems in implementing cost-reducing technology (ELI 1998; Swift 1997). Part of the reason why compliance cost is higher in steel therefore has to do with the rigidity of the environmental regulation affecting the industry.

Porter attempts to rebut the findings of these plant-level studies, primarily by pointing out that few find significant effects, and all operate in the context of the highly imperfect current regulatory system, which is biased against innovation. He states:

"A number of studies have failed to find that stringent environmental regulation hurts industrial competitiveness. Meyer (1992, 1993) tested and refuted the hypothesis that U.S. states with stringent environmental policies experienced weak economic growth. Leonard (1988) was unable to demonstrate statistically significant offshore movements by U.S.

firms in pollution-intensive industries. Wheeler and Mody (1992) failed to find that environmental regulation affected the foreign investment decisions of U.S. firms. Repetto (1995) found that industries heavily affected by environmental regulations experienced slighter reductions in their share of world exports than did the entire American industry from 1970 to 1990. Using Bureau of Census data of more than 200,000 large manufacturing establishments, the study also found that plants with poor environmental records are generally not more profitable than cleaner ones in the same industry, even controlling for their age, size and technology."

He concludes after his review that:

"Of course, these studies offer no proof for our hypothesis, either. But it is striking that so many studies find that even the poorly designed environmental laws presently in effect have little adverse effect on competitiveness. After all, traditional approaches to regulation have surely worked to stifle potential innovation offsets and imposed unnecessarily high costs of compliance on industry ... Thus, studies using actual compliance costs to regulation are heavily biased towards finding that such regulation has a substantial cost. In no way do such studies measure the potential of well-crafted environmental regulations to stimulate competitiveness."

B. Elements Supportive of the Porter Hypothesis

While economists have been generally unwilling to accept Porter's position that a private firm's costs may decline or reach zero due to environmental regulation, they do agree that net social costs of regulation can be positive. These findings stress general equilibrium effects of regulation, and require a careful weighing of social benefits versus private costs.

As described in greater detail below, traditional economics also supports the importance of several of the factors that may lead to reducing the cost of environmental regulations. First, most economists would agree that the way we regulate is important and would concur with Porter's principles for innovation-friendly regulations. In fact, inflexible regulation can impose competitive disadvantages in industries where foreign competitors face more flexible forms of regulation (MIEB 1995). A recent study comparing ex-ante and ex-post regulatory costs also suggests that actual costs tended to be lower than predictions more often for regulations using a flexible or market-based design (Harrington et al. 1999). The structure of regulations may actually be the major determinant of their cost, an issue discussed below.

A second traditional finding would be that environmental regulation may lead to innovations in compliance technology, which would be expected to reduce costs over time. A third would be that there can be competitive advantages or benefits to certain industries or firms due to environmental regulation. Most frequently cited is the environmental technology industry, many parts of which would not exist were it not for environmental regulation. Another beneficiary would be large firms, which may have a comparative advantage due to their size and research capability when an industry sector is subject to stringent new environmental regulation. Finally, traditional economists may accept that there may be first mover advantages to firms in a country which exerts leadership in an environmental area if other countries are expected to follow suit later.

These assertions, although consistent with the Porter hypothesis, are not reflective of his broader statements concerning the possibility or even likelihood of cost savings to private firms through process improvements and innovations due to regulation. It is this latter issue this report examines.

III. Identifying the Factors Relevant to the Porter Hypothesis

This research is intended to explore the legal, social and economic factors that may affect Porter's hypothesis that "properly designed environmental standards can trigger innovation that may partly or more than fully offset the costs of complying with them." This hypothesis does not state that innovations will always be profitable, but in this research we interpret it to state that expected innovation would significantly reduce the costs otherwise occasioned by the environmental regulation (Porter 1995b).

We first examine the influence that the kind of environmental regulatory framework exerts on costs. Second, we examine factors which may reduce costs in response to environmental regulation that arise from within a firm, and thirdly external factors such as industry structure, the timing of regulation, and social or sectoral economic benefits.

A. The Design of Environmental Regulation

A key to the Porter hypothesis requires that environmental regulation cause a firm to re-examine its process technologies to find greater efficiencies and cleaner processes. This requires two things of the regulation - that it be strict, as small changes in standards will not cause such a review, and that it not impose rigid requirements, permitting innovation and change in production processes.

The strictness of regulation has been called "the most important factor" influencing radical technological innovation (Ashford 1994 at 297). Otherwise, regulation only leads to incremental or end-of-pipe changes; the incentives to create more fundamental innovations are not present. Ashford points out that regulation can be stringent because it requires a significant reduction, because it imposes significant costs, or because compliance requires a significant technological change. Thus, although early environmental laws rarely stimulated innovation, OSHA regulations were more likely to do so due to their stringent nature (OTA 1995).

The design of an environmental regulation also exerts a significant effect on the cost of compliance. Although this issue is regularly mentioned by economists studying costs, it rarely forms an integral part of their assessments, in part because it is difficult to quantify. In the United States, however, the nature of regulation may determine to a great extent the cost of compliance, and is therefore an independent variable which should be taken into account in cost studies.

Porter emphasizes the importance of this issue, and states:

"[T]he current system of environmental regulation in the United States often deters innovative solutions or renders them impossible. The problem with regulations is not its strictness. It is the way in which standards are written and the sheer inefficiency with which regulations are administered. Strict standards can and should promote resource productivity. The United States regulatory process has squandered his potential, however, by concentrating on cleanup instead of prevention ...." (Porter 1995a at 129).

He identifies eleven design factors for innovation-friendly regulation (Porter 1995a at 124):

1. Focus on outcomes, not technologies;
2. Enact strict rather than lax regulation;
3. Regulate as close to the end user as practical, while encouraging upstream solutions;
4. Employ phase-in periods;
5. Use market incentives;
6. Harmonize or converge regulations in associated fields;
7. Develop regulation in sync with other countries or slightly ahead of them;
8. Make the regulatory process more stable and predictable;
9. Require industry participation in setting standards from the beginning;
10. Develop strong technical capabilities among regulators;
11. Minimize the time and resources consumed in the regulatory process itself.

Other economists and writers have agreed strongly with his views (Jaffee 1995 at 152; Hahn and Stavins 1991). However, in general few have taken this issue into account in subsequent studies of plant-level costs incurred by environmental regulation. Instead, they attribute those costs to economic factors. If, however, the economic response of firms is severely constrained by regulatory design, as we argue, the studies mentioned above might be better interpreted as studies reflecting the design of regulatory systems, not of the true economic costs of the regulation.

Economists have identified particular problems with environmental regulations, to which we will add more general observations. One situation cited by economists is that the new source bias in some environmental laws can discourage investment in new, more efficient plants. This is certainly the case with some laws, such as the Clean Air Act, which for its first decades only regulated new sources and not existing sources, creating a barrier to new investment, especially in the utility industry (Nelson, Tietenberg and Donihue 1993). Additional issues involve the strictness of regulation, and whether they provide firms with adequate time to develop cost-effective responses.

However, practitioners and other writers have identified a more widespread set of problems in current environmental regulation, especially concerning the widespread "best available technology" type standards. Such standards are inflexible and may severely limit innovation, creating higher costs than necessary.

This subject has been extensively treated in the literature on regulatory barriers. A federal advisory committee on the subject has published several reports on the nature and strength of the barriers to innovation created by current forms of regulation (USEPA 1991, 1993). A report and survey by the Environmental Law Institute confirm these barriers, and point to the need for overall performance standards (ELI 1998; EPA 1998). Several other institutions have also recently completed studies on the reform of our environmental laws (Davies 1998). These analyses have identified overlapping problems in the current design and implementation of environmental laws that discourage least-cost compliance and innovation.

Although this study will not detail regulatory barriers, a brief overview serves to illustrate the embedded and pervasive nature of this problems in our major environmental laws. A central problem identified has been that the design of most standards under the Clean Water Act and Clean Air Act require EPA to establish technology-based discharge rate limits based on "available" or "feasible" technologies. For air such standards include "reasonably available control technology" (RACT) for existing sources, "best available control technology" (BACT) for new sources and maximum achievable control technology (MACT) for hazardous pollutants. Water standards include "best available technology economically achievable" (BAT). [42 U.S.C. 7502(c)(1)(RACT); 42 USC 7475(a)(4) (BACT); 42 U.S.C. 1311(b)(2)(A) (BAT)]. While these standards avoid the pitfalls of setting technology mandates, they severely limit innovation for many reasons:

a) *restrictive design*: rate-based standards inherently limit technology options compared to mass-based performance standards, as they discourage or may even preclude technologies which reduce amounts but not rates. They may also emphasize, or even dictate, end-of-pipe compliance solutions instead of the process changes which can lead to the results suggested by the Porter hypothesis.

b) *require "available" and "control" technologies*: many key environmental standards require EPA to set standards based on "available" technologies already in use, a backward-looking standard which may preclude innovative or "outside-the-box" solutions; the laws typically also require EPA to base standards on "control" technologies, reinforcing the end-of-pipe paradigm.

c) *no incentive for further progress*: fixed rate standards create no incentives for compliance that goes beyond the stated limits.

d) *limitations of the point source context*: almost all environmental laws fix the specific rate limits for basic and hazardous pollutants on each specific point source based on the above standards. Even if new process technologies are cleaner overall, they cannot be permitted if one point source exceeds a single parameter, creating inflexibility.

e) *permitting system reinforces conservative choices*: once EPA has gone through the often-adversarial process of identifying the acceptable "available" "control" technologies, industries and permit writers face high risks deviating from these standards. While such regulation may temporarily increase a certain technology use, it then blunts experimentation and innovation, both because it does not encourage further progress, and because the adversarial and conservative nature of permitting under this method tends to reject the innovative or new (Strasser 1997; EPA 1993, 1991).

f) *high costs of delay*: our current system takes one to two years to permit new or modified major pollution sources due to the need to apply technology-based rate standards to every point source. This can be the greatest cost imposed by pollution control. In contrast, mass-based performance standards can be designed to be much more efficient - transactions under the Acid Rain Program for instance generally take less than 24 hours.

g) *federalized permitting system*: our federalized permitting systems can create high barriers to commercializing innovative technologies under "ACT" type standards because all the barriers to acceptance must be repeatedly overcome in each state until the technology becomes generally accepted. In contrast, overall or mass-based performance standards require government monitoring but not technology review, greatly lowering the barriers created by federalized systems.

A different set of regulatory issues generally govern solid and hazardous wastes. These are government by different statutes, notably the Resource Conservation and Recovery Act (RCRA), and Superfund legislation. Although their design is not based on "ACT" type standards, regulatory and industry officials consider our environmental systems regarding wastes as the most problematic of the major environmental statutes in a recent survey (EPA 1998b at 17). RCRA requires "cradle to grave" tracking and treatment of hazardous wastes, which may preclude "cradle to cradle" recycling; its definition of waste, for example, may cause process chemicals that would otherwise be reclaimed and reused to be labeled as wastes and force their disposal (ELI 1998a).

Perhaps the best example of the problems with technology prescriptions and rate-based standards is offered by the history of regulation of sulphur dioxide by electric generating facilities, which allows a retrospective review of the effects of different regulatory strategies. Cost estimates have been made of various regulatory strategies to attain a similar reduction level. Mandating scrubbers, which allows no room for innovation except in scrubber technology, is the most expensive, at $7 billion a year. Continuing the use of the rate-based emissions standards in effect for new sources from 1977 to 1990 also results in technology prescriptions and would cost $4.5 billion. The mass-based or performance standard adopted in 1990 - an emissions cap and allowance trading system - was estimated to cost $2.5 billion, and even less if the barriers to trading are overcome (Burtraw, 1996; ELI 1998). Each of these systems allows progressively greater room for technology choice and innovation, and as can be seen, have a dramatic impact on overall cost. Interestingly, fulfilling even optimistic interpretations of the Porter hypothesis, the current flexible system allows about a fourth of firms to comply at a profit due to unexpected innovation (Ellerman et. al. 1998). Another study compares the U.S. and Swedish pulp and paper industries, and found that Swedish producers adopted in-process innovations earlier than their U.S. counterparts, in part because of inflexibility imposed by U.S. regulations (MIEB 1995). Studies of pollution prevention also points to the need to reform regulatory barriers (Strasser 1997; Boyd 1998a at 43).

Overall, many of the problems of inflexibility in our current system could be avoided by better designed regulations, such as mass-based standards, emissions cap and trading programs, and a greater effort to set overall performance standards (Porter 1995a, Ashford 1985, Jaffee 1995). The strictness of the regulation is also important in promoting more radical innovations.

The point to be made is that our current regulatory system provides a highly imperfect and variable arena in which to test the Porter hypotheses. The design of regulations appears to have at least as great an impact on the costs of compliance as the traditional economic forces which might lead to innovation. Any empirical study of cost therefore faces the difficult task of distinguishing between the lack of innovation caused by the rigidity of the regulatory system and that caused by the inability of the firm to implement cost-effective solutions.

B. Economic and Other Factors Within the Firm

This section explores the reasons that arise from within firms that may affect a firm□s ability to innovate in response to environmental regulation, and that may lead to the situation that the Porter hypothesis predicts. In general, the internal structure and functioning of large firms plays a major role affecting a firm□s decisions whether to investigate or invest in potential pollution prevention solutions, and potentially also in suboptimal behavior.

A fundamental tenet of the Porter hypothesis is that regulation may lead to process innovations and other improvements that are more efficient and hence profitable. Porter stresses "that pollution often is a form of economic waste... [P]ollution ... is a sign that resources have been used incompletely, inefficiently or ineffectively" (Porter 1995a at 122). Regulation therefore forces investigation into improved resource productivity and may lead to more efficient processes. In this way, pollution prevention actions parallel overall quality concerns, which include the need to use inputs more efficiently, eliminate the needs for hazardous substances, hard-to-handle materials, and eliminate unneeded activities. The kinds of process improvements to comply with environmental regulations that would be expected to lead to cost savings include:

- higher yields;
- better utilization of existing materials;
- substitution of less costly materials;
- higher consistency and quality;
- pollution often reveals flaws in the product design or pollution process;
- savings through reduced costs of handling, storage and disposal of discharges;
- pollutant stream becomes a useable resource or product.

Environmental regulation may also lead to the discovery and development of wholly new processes and products. These more fundamental process changes may require companies to make a thorough examination of alterative technologies and processes and invest in significant research, in contrast to the more incremental changes typically under the control of plant personnel, described above. The parallel between pollution prevention and efficiency means the research is focused on more efficient and productive processes, which may be more profitable and hence rewarding in itself.

This may be the least acceptable element of the Porter hypothesis to most economists. According to Jaffee: "Economists have been generally unsympathetic to these arguments because they depend upon firms being systematically ignorant of profitable production improvements or new technologies that regulation brings forth" (Jaffee 1995 at 155). While they are willing to admit that regulation may stimulate innovation in compliance technology, and to some extent innovation in processes, such as patents, they believe it unlikely that this can greatly offset the costs otherwise occasioned.

Research on within-firm behavior and decision-making reveals many factors that may affect decisions concerning environmental compliance. On the one hand, financial, strategic and technological considerations may create disincentives for investing in potentially attractive pollution prevention for legitimate business reasons. However, internal systems for knowing, communicating and managing are more imperfect within firms than is appreciated (Sinclair-Desgagné 1997; Gabel 1998). Such factors are rarely taken into account in evaluations of costs of compliance, and provide a rationale why reorganizing forces like environmental regulation can result in attractive cost savings. This section sets forth factors that may make the Porter hypothesis more likely, and where additional investigation may be warranted.

Before examining these research issues, we note that several studies demonstrate that financial, strategic and technological considerations may create disincentives for investing in potentially attractive pollution prevention for legitimate business reasons. These range from small firm characteristics that preclude any consideration of alternatives, to high hurdle rates for new investment, to the lock-in effect of high-cost capital equipment that is already in place. These may in fact support the Porter hypothesis, as they show that opportunities to take cost-effective pollution prevention actions may exist that firms would be forced to implement if regulations were adopted. However, they also show how normal business constraints may discourage investment in pollution prevention.

A six-industry study of barriers to innovation by the Environmental Law Institute found that "normal economic and business conditions" created the principle barrier to implementing innovative and cost-saving technologies in three of the six industries studied. In the dry cleaning industry, the small size and lack of research or financial capacity in virtually all firms in the industry precluded research or development of several promising alternatives to the use of perchloroethylene, the principal solvent used in dry cleaning. In the pulp and paper industry, the high capital cost of equipment in place meant that $10-20 million per mill is needed to retrofit or redesign the equipment to achieve greater pollution reductions. This, together with the low number of new mills being built, limits the adoption of known pollution prevention technologies. Only in the third case, wastewater treatment, was it apparent that undue conservatism and resistance to change by conservative owners, typically governments, inhibited innovation (ELI 1998).

A similar conclusion was reached at the firm level, in a study of three cases of unsuccessful implementation of pollution prevention opportunities by individual firms (Boyd 1998a):

> "As the cases show, basic concepts from business and financial theory suggest that the firm□s investment decisions were financially rational. This is contrary to the view that firms suffers from a myopic inability to appreciate cost-saving P2 investments. Instead, significant unresolved technical difficulties, uncertain market conditions, and, in some cases, regulatory barriers or insufficient emissions enforcement, rendered the investments financially unattractive. In many cases, the mystery of why firms do not pursue P2 opportunities can be resolved by simply having a deeper understanding of the costs, benefits and risks associated with those investments."

In this study, two of the three firms failed to implement pollution prevention (P2) actions due to legitimate internal business reasons. In one, the firms failed to implement a P2 solution because it had a high internal hurdle rate for investment of 86%. This high benchmark was created because another possible investment delivered this rate of return, and absorbed the capital available to the firm. In another case, a firm□s restructuring and desire to not invest in under-performing sectors of the business precluded an investment in an otherwise profitable pollution prevention opportunity until that sector of the firm was spun off as an independent unit.

1. Environmental regulation may increase research

An argument favoring the Porter hypothesis is that environmental regulation leads firms to additional research regarding compliance options and possible process changes which would not have been undertaken absent the impetus of regulation. This research may result in process improvements and new technologies that are profitable.

There are many examples of profitable results from such research, that reveal that environmental regulations created win-win situation by forcing firms to re-examine assumed barriers to innovative technologies. The Acid Rain Program forced firms to test assumptions about barriers including rail transport bottlenecks and capability of existing boilers to handle earthy western low-sulphur coal without major modification. Both barriers were surmounted by investment in one case and innovation in fuel blending technology in the other. Regulations of the distilled spirits and beer industries have led to the discovery of new waste treatment technologies that eliminate wastes while creating profitable by-products. Regulation of the dry cleaning industry have led to testing of "wet cleaning" technologies that tests show are fully equivalent and cheaper (ELI 1998 at 60; UCLA 1996). These again suggest the importance of the role of regulation in prompting additional research.

Traditional economic theory would not agree that such research should often produce significant economic gains. The "real question is not whether searching produces new ideas but whether particular searches that are generated by regulation systematically lead to more or better ideas than searches in which firms would otherwise engage" (Jaffee 1995 at 156). Since firms are presumably engaged in a profit-maximizing amount of research before the environmental regulation placed greater needs on them, the additional research prompted by regulation should not in theory be consistently profitable.

There are reasons why firms may in fact systematically under-invest in research. The first is that evidence from current businesses indicate that the highly competitive global marketplace has caused many basic manufacturing industries to dramatically reduce research budgets, especially for basic research. A survey of research of environmental technology firms revealed that even these generally devote only 2-3% of revenues to research, and 90-100% of this is applied research with short-term time frames (ELI 1997b). Research by the National Academy of Sciences reveals similar trends in industry at large (NAS 1995). The second is that the full benefits of research may not be captured by the firm making the research, but may benefit the entire sector or economy. This is treated below in section C.

2. Organizational structure and incentives in firms

The literature on firm behavior and environmental issues reveals that many aspects of firm structure and incentives do not foster innovation. Findings include problems due to production staff not being responsible for environmental compliance (OTA 1994); how environmental costs are treated in incentive structures (Gibbons 1998) and in accounting systems (Ditz 1995); lack of time; communications structures (Bolton and Dewatripont 1994); the influence of habits and routines (Gabel and Sinclair-Desgagné 1998); and industry rigidity.

Manufacturing firms have typically responded to the need to comply with environmental regulations by creating a separate environmental division within the firm, and placing environmental costs in overhead. Both actions tend to divorce environmental compliance from the production process and employees within the companies, where process expertise resides and pollution prevention responses would be best developed. As a consequence, "many firms overlook sources of savings such as energy reduction and pollution prevention, reorientation of materials flow, reduced inventory, and improved quality, in favor of either increased output or direct cost reductions related to production" (OTA 1994 at 247).

A major issue concerns the principal-agent problem, where the incentives of the employer differ from those of the employee, and the employer lacks the resources to monitor the employee effectively (Sinclair-Desgagné & Gabel 1997; Holmstrom & Milgrom1992). Some researchers have found that corporate structures are usually such that individuals within the corporation have no incentive to seek out and undertake pollution control measures. The Office of Technology Assessment identified that "responsibility for finding pollution prevention opportunities may not rest with those most capable of doing so," and they also found a general lack of organizational reward for reducing waste (OTA 1994 at 246; Roy 1992). They also found that "operating managers often emphasize output maximization, making it hard for them to give priority to pollution prevention investments" (OTA 1994 at 247). According to one author "waste reduction opportunities were seldom considered until circumstances virtually forced plants to review their waste management practices" (Sarokin 1985 at 143). The corporation thus fails to pick the "low-hanging fruit" (Gabel and Sinclair-Desgagné 1998) of cost savings achieved through pollution control.

Another problem pertains to the firm's limited ability to monitor the practices of those responsible for or capable of achieving pollution reduction. Limitations on staff time and attention are frequently-cited problems in identifying why profitable pollution prevention actions are not undertaken by firms until regulation forces attention to these issues (OTA 1994). Thus, there arises a form of "bounded rationality," (Simon 1987) in which the desire of those at the top of the corporate hierarchy to achieve pollution reduction can be frustrated by inertia at the lower levels, where reduction can actually be accomplished. Some manufacturing firms have responded to the need to comply with environmental regulations by creating a separate environmental division within the firm, and placing environmental costs in overhead (Florida 1996 at 93). This still has the effect of divorcing environmental compliance from the production process and employees within the companies where process expertise resides, and pollution prevention responses best developed.

Another line of research has emphasized the coordination failure due to habits and procedures formed around production processes, and which keep a firm away from the global. According to Cyert and March (1992), AThe way in which the organization searches for alternatives is substantially a function of the operating rule it has.Y The organization uses standard business procedures and rules of thumb to make and implement choices. In the short run these procedures dominate the decisions made.@ By forcing a firm to reconsider its actual processes and re-engineer its existing routines, stricter environmental regulation might actually bring the firm closer to its own private optimum (Gabel and Sinclair-Desgagné 1998).

These problems have nevertheless been overcome in several instances. "Total quality environmental management" is an increasingly popular management technique, whereby production workers are involved in the product quality improvement process (Florida 1996 at 91). This technique directly addresses the organizational obstacles to pollution reduction inherent in corporate structures. Individual leadership on the part of committed individuals or a group of committed individuals can also compensate for poor organizational structure. One study of several differing industries identified the key role played by the CEO in firms' environmental initiatives (OTA 1994 at 247). A report by a steel company identified that one plant implementing profitable investments in pollution prevention did so primarily because the plant manager was individually motivated (ELI 1997a).

Another study of environmental compliance in the chemical industry found that several elements of firm organization played a key role in whether or not the plant carried out pollution prevention projects. "Plants that had one of three individual program features -- cost accounting, employee involvement and leadership from both environmental and other departments -- had statistically significantly more source reduction activities on average than plants lacking these features." The study also found that plant size was statistically significant - larger plants were generally able to do more (Dorfman 1992 at 31,35). Still, in the majority of cases in which environmental improvements are achieved, they are merely the "unintended consequence of broader efforts to improve industrial performance" (Florida 1996 at 94; Florida 1999).

3. Accounting information consistently under-represents the benefits of pollution reduction

A considerable literature has developed on business practices in accounting for environmental costs. This indicates that accounting systems often fail to capture the full cost of managing waste-streams, and hence understate the benefits of reducing those waste-streams through pollution prevention (Ditz 1995; Porter 1995b at 114; OTA 1994 at 247). Generally, whether an investment in pollution prevention is projected to be profitable depends largely on how the firm accounts for savings from pollution control. For example, accounting systems which have been designed for financial management and reporting typically fail to allocate environmental costs to the cost-creating activity (EPA 1992, Strasser 1996 at 47). Environmental costs, which are typically not large, tend to be treated as overhead, reducing perceived benefits from environmental projects (Ditz 1995). In one study, firms with some kind of environmental accounting system had three times the number of source reduction activities as plants with no cost accounting systems (Dorfman 1992 at 31).

OTA found that a large portion of firms do not perform discounted cash flow analysis on pollution prevention projects, which are often regarded simply as mandatory environmental projects that historically have cost the firm money; in addition, conventional accounting underestimates longer-term benefits of pollution prevention projects (OTA 1994 at 248; see also Sinclair-Desgagné & Gabel 1997).

4. Overcoming static mind-set and industry inertia

Perhaps the most important, yet difficult to quantify factor contributing to the Porter hypothesis is the issue of static mind-set and industry inertia. However, the firm and sector based studies above that reveal, albeit anecdotally, win-win responses to environmental regulation, consistently point to this issue. Firm management did not regard waste reduction as within their priority concerns. Their training concerned other issues, and there was little institutional focus on the issue absent regulation. "Pollution prevention efforts within business organizations today are more limited by organizational culture than by available technology" (Strasser 1996 at 44). This is not wholly irrational — firms invest heavily in developing routines to handle their day-to-day business, and changing routines can not only be difficult but also costly (Gabel and Sinclair-Desgagné 1998 at 100). Moreover, firms may face disincentives to environmental self-auditing by having the disclosed information used against them by a regulator to assess fines and penalties (Pfaff and Sanchirico 1998).

A relevant literature here is that concerning industry behavior in response to technology change. This literature supports the finding that there is considerable rigidity in business response to potential opportunities for change. Although these are considerable differences between sectors, one finding is that mature firms tend to become rigid in response to technology change opportunities. Another is that radical technology changes are likely to come from sources outside the industry. (Strasser 1998 at 19-23; Ashford and Heaton 1983 at 126; Utterback 1994). Porter's broader research on competitiveness also highlights the importance of outside pressure in overcoming organizational inertia and fostering creative thinking (Porter 1995a; Roy 1992; Rejeski 1995).

C. Reasons arising from factors from without firm

1. Cross-industry gains - some costs won't be borne by firms until all must do so

Environmental regulation may stimulate research and other action that makes economic sense only if all firms in the industry must participate in the activity together, or if the benefits of the activity are spread over all firms. This is especially true of research, as though individual firms must pay for the research, all firms in the sector may benefit over time as the results of the research become diffused (Jaffee 1995 at 156). To the extent research is important to maintaining a nation's competitive advantage in an industry, environmental regulation has a positive effect by requiring more research than a private firm optimum.

2. Industry structure may preclude innovation.

The structure of some industries creates significant barriers to research and action to take advantage of innovations. These include industrial sectors dominated by small businesses, which lack the capacity and finance to mount significant research efforts, and sectors such as public utilities which have been insulated from competitive pressures and are slow to innovate (OTA 1994 at 246-247).

Industries dominated by small business lack both the technical and financial capacity to conduct the necessary research efforts to identify new opportunities. One example is the fragmented U.S. printed wiring board industry, which lost global market share because of its failure to innovate competitively (MIEB 1995). Another such industry is the dry cleaning industry, dominated by very small firms, and where the industry has financed little research on alternative processes. The most significant research on several viable alternative technologies for dry cleaning that promise win-win solutions has been financed by sources outside the industry (ELI 1997a).

Public utilities are another sector where barriers to innovation stem in part from the nature of the industry. Since these have traditionally been public monopolies with defined service areas, they are insulated from commercial pressures and have been slow to innovate. According to one former professor of waste-water engineering, "The stuff I was looking at in the 1970's was just improving on what the Egyptians did 5,000 years ago. But that's changing now" (Environmental Business International 1995). A market structure that supports rivalrous behavior among firms within the industry and new entrants is an important condition supporting innovation (Strasser 1997).

3. Outside experts tend to promote end-of-pipe solutions

Another factor cited for the slowness to innovate in utility sectors has been the structural problems in the consulting industry which municipal utility plant owners rely on to identify and install technologies. Outside consultants play a significant role in the technology compliance of many firms. This is especially true of public utilities, where municipal owners have no research capacity, and small business (OTA 1994 at 247). These outside experts have only limited capacity or incentive to promote low-cost process changes for numerous reasons, including their lack of familiarity with a client's particular process, their ties to particular vendors or technologies, their readiness to promote end-of-pipe solutions due to adversarial USA permit process, or simply because their fees are higher with higher cost solutions. Also, there are economic drivers for these outside consultants to prescribe traditional treatment methods, instead of lower-cost alternative treatments which are widely available, as their fees are higher and risks are lower.

4. Regulation may eliminate inefficient plants

Economists would agree that environmental regulation may force the less efficient plants in an industry to close, which may boost overall productivity. Jaffee (1995) suggests this happen in the steel industry in the 1970s. A related argument is that environmental regulation leads to "upgrade production facilities or invest in new, more productive facilities" (OTA 1994 at 85).

An unintended consequence of environmental regulation may be that it favors the success of large plants with greater research and adaptations capacity than smaller entities. This contributes to increased economic efficiency in situations where the larger firms are also more economically efficient than the smaller ones.

In addition, older technology tends to be less efficient and therefore more polluting, so additional environmental regulation may discriminate selectively against such older equipment, forcing its retirement by the firm. Although this may raise average productivity of the industry, an economist could point out that the older equipment had remaining useful economic life absent the regulation, so its retirement in favor of investment in newer equipment is not necessarily efficient.

5. Regulation adds green market

Another area where economists would agree is that environmental regulation can give a nation's industry first mover advantages in situations where international environmental regulation is also expected to become more stringent in the future (Jaffee 1995; OTA 1994 at 86). According to Porter, "innovation that US environmental regulation spurred is allowing it to gain position in international markets where similar needs are growing" (Porter 1995 at 127). Put another way, regulation often creates the emerging markets for environmentally cleaner products and processes. The far-sighted company can anticipate impending regulation and gain a competitive advantage by beginning development of cleaner products and processes earlier. This is especially true in cases where these products or processes are patentable or otherwise protectable as intellectual property. On the other hand, this company may lose if green demand is not forthcoming, and the company cannot charge a premium for its product.

In addition, early compliance may allow the company to sell its compliance technology to others. Examples can be found in the pulp and paper sector (MIEB 1995), in distilling and brewing where Bacardi and Anheuser-Busch both successfully market waste processing technologies originally designed for environmental compliance (ELI Forum 1993; Beers 1993).

The opportunity to market green products is widely promoted by advocates of sustainable development, who suggest that demand for green products may be important (Hart 1997). The U.S. Environmental Protection Agency's initiative to induce computer manufacturers to build more energy-efficient computers for example was particularly effective, as it applied to all computers purchased by any U.S. governmental agency. The refrigerator market in Germany may have been driven by desires of German consumers to purchase more energy-efficient refrigerators that also avoid the use of ozone layer-depleting chlorofluorocarbons (MIEB 1995). Although this may provide a boost to competitiveness of firms in industries where international demand in greener products is growing, it may not be significant for most industries.

6. Timing in regulation life cycle

Few studies have focused on the relevance of the timing of regulation on compliance cost. The opportunities to develop cost-saving approaches or win-win solutions are not equal at all times during the life cycle of regulation of a pollutant. With many pollutants there are more opportunities for such low-cost abatement actions when a pollutant is first being regulated, due to the lack of focus on the problems and lack of any previous action. In contrast, there may be expected to be relatively few undiscovered cost-effective actions in a traditionally regulated pollutant where standards are being raised to close to 100% abatement.

This situation can be empirically described for several regulated or potentially regulated substances. One is carbon dioxide (CO_2), where The National Academy of Sciences estimates that using existing technology, the United States could reduce emissions of CO_2 by an initial 25% at a profit, a second 25% at low or not cost, and thereafter with a steadily rising cost curve for the remaining 50% (NAS 1991 at 61). A similar scenario exists for reducing NO_x emissions from vehicles. Initially, emissions of existing fleets can be reduced at a profit by such basic actions as improving maintenance, especially of diesel engines, where reductions of up to 60% can be achieved with little net cost. After this point costs increase steadily, with the costs of current efforts to move from roughly 95% to 98% control requiring such expensive technologies as the addition of a second catalytic converter (International Bank for Reconstruction and Development 1996).

However, other studies indicate "efficiency-oriented opportunities continue to be found by plants that had previously achieved significant reductions in waste generation" (Dorfman 1992 at 90). The literature regarding total quality control and compliance with International Standard Organization (ISO) standards for total quality control and environmental quality also indicate that firms find it in their interests to continually seek improvement in total quality.

7. There may be net economic gains to society due to market imperfections

It is widely acknowledged that net social benefit may rise with greater environmental regulation, although there is a vigorous debate as to whether specific regulations have net benefits. In general, several economic analyses have concluded that, leaving aside aesthetic and other purely qualitative benefits, US air regulations have had significantly positive net benefits, whereas water regulations have had marginal or negative net benefits (Davies 1998 at 135; Hahn 1996).

Social return rates from environmental quality investments are often higher than private, especially because of the externality cost of pollution. Lower levels of pollution may lead to lower health care costs, increased labor productivity and lower costs in other parts of the economy resulting from reduced pollution (OTA 1994 at 83; OECD 1989). Lower pollution can also improve water quality, lowering costs to firms using process water, and has significant positive benefits to agriculture and aspects of our economic infrastructure such as buildings (Davies 1998). Regulation may also confer industry- or society-wide economic benefits, some of which would accrue to firms, reduce production costs or enhance factor productivity (Stewart 1993).

Studies by Repetto have shown how the productivity of specific industries can be dramatically altered by including measurement of environmental externalities. For example, conventional measurement of productivity in the electric power sector declined 0.35% per year from 1970 to 1991; after taking into account benefits of pollutant reductions on the economy in general, the sector's productivity rose by as much as 0.68% per year.

However, while the net benefits of environmental regulations increase overall social welfare, the marginal contribution of one regulation to social welfare is not likely to be so significant to a particular firm that it overcomes the private cost to the firm of complying with that regulation. However, the overall cost to the firm of complying with all environmental regulations may be reduced by improvements to worker health and productivity, and other benefits that result from environmental regulation. Also, regulation of downstream processes and finished products can create emerging markets for upstream suppliers to the regulated industry. This is generally only true, however, when the downstream market is sufficiently large and important to the upstream industries (MIEB 1995).

IV. Conclusion

The overview given by this paper reveal many considerations affecting the achievement of win-win environmental solutions, and issues that require further research. External to firms, the design of environmental regulations is shown to play a major role in the extent to which firms may seek innovative solutions, and the consequent costs of compliance. This may overshadow strictly economic considerations today in the United States. Studies of strict but flexible regulatory programs, such as cap-and-trade programs, show that unexpected innovation may generally be expected to reduce significantly the cost of compliance.

Within industries and firms, a large variety of factors, including management, communications and accounting structures, are identified that may preclude efficient attainment of pollution prevention practices. Alternately, they show that considerations of risk, strategy and other business factors may discourage otherwise beneficial pollution abatement options. These factors help to explain why Porter's hypothesis may be realized in certain instances, although their richness and complexity also indicates the need for greater understanding and analysis.

Sources

Arnold, M. & R. Day, 1998. THE NEXT BOTTOM LINE: MAKING SUSTAINABLE DEVELOPMENT TANGIBLE. World Resources Institute, Washington, D.C.

Ashford, N., 1994. *An Innovation Based Strategy for the Environment*, in WORST THINGS FIRST. Resources for the Future, Washington, D.C.

Ashford, N., C. Ayers & R. Stone, 1985, *Using Regulation to Change the Market for Innovation*, 9 Harvard Env. Law Rev, 419.

Ashford, N. & G. Heaton, 1983. *Regulation and Technological Innovation in the Chemical Industry* 46 Law and Contemporary Problems, 109.

Beers, Allen, 1993. *First year Operation of Two Brewery Anaerobic Treatment Systems.* Unpublished document, Anheuser Busch Companies, Inc.

Bolton, P. and M. Dewatripont, 1994. *The Firm as a Communication Network*, 109 Quarterly Journal of Economics 809.

Boyd, James, 1998a. *Searching fr the Profit in Pollution Prevention: Case studies in the Corporate Evaluation of Environmental Opportunities.* Resources for the Future, Discussion Paper 98-30 (April).

Boyd, James, 1998b. *The Benefits of Improved Environmental Accounting: An Economic Framework to Identify Priorities.* Resources for the Future, Discussion Paper 98-49 (September).

Burtraw, D. and B. Swift, 1996. *A New Standard of Performance: An Analysis of the Clean Air Act's Acid Rain Program.* 26 Envir. Law Rep. 10411 (August).

Cyert, R. and J. March, 1992. A BEHAVIORAL THEORY OF THE FIRM (Blackwell).

Davies, C. and J. Mazurek, 1998. POLLUTION CONTROL IN THE UNITED STATES: EVALUATING THE SYSTEM. Resources for the Future, Washington, D.C.

Ditz, D. et al., 1995. GREEN LEDGERS: CASE STUDIES IN CORPORATE ENVIRONMENTAL ACCOUNTING. World Resources Institute, Washington, D.C.

Dorfman, M., W. Muir, & C. Miller, 1992, ENVIRONMENTAL DIVIDENDS: CUTTING MORE CHEMICAL WASTES (INFORM, New York).

Environmental Business International, 1994. *Innovative Technologies Poised for Growth in Water/Wastewater.* X Environmental Business Journal, Vol. VII (Nov/Dec).

Environmental Law Institute, 1997a. PROCEEDINGS OF THE WORKSHOP ON SPENT PICKLE LIQUOR. Washington, D.C. (April).

Environmental Law Institute, 1997b. RESEARCH AND DEVELOPMENT PRACTICES IN THE ENVIRONMENTAL TECHNOLOGY INDUSTRY. Washington, D.C.

Environmental Law Institute, 1998. BARRIERS TO ENVIRONMENTAL TECHNOLOGY INNOVATION AND USE. Washington, D.C. (January).

Environmental Law Institute Forum, 1993. *A Remarkable Process.* ELI Forum at 10 (July/August).

Florida, Richard (1996) *Lean and Green: The Move to Environmentally Conscious Manufacturing.* 39 California Management Review 39:80-105.

Florida, R., M. Atlas & M. Cline, 1999. *What Makes Companies Green? Organizational Capabilities and the Adoption of Environmental Innovations.* Carnegie Mellon University (Feb.)

Gabel, H.L., and B. Sinclair-Desgagné (1998) *The Firm, its Routines and the Environment,* Chapter 3 in the International Yearbook of Environmental and Resource Economics.

Gibbons, R., *1998. Incentives in Organizations*, 12 Journal of Economic Perspectives 115.

Gray, W. & R. Shadbegian, 1995. *Pollution Abatement Costs, Regulation and Plant-level Productivity.* National Bureau of Economic Research, Working Paper #4994 (Cambridge, MA).

Hahn, R. & R. Stavins, 1991. Incentive-based Environmental Regulation: A New Era from an Old Idea, *Ecology Law Quarterly* 1991, pp. 1-42.

Hahn, Robert. 1996. *Regulatory Reform: What do the Government Numbers Tell US?* in Robert W. Hahn (ed.), RISKS, COSTS, AND LIVES SAVED: GETTING BETTER RESULTS FROM REGULATION. New York: Oxford University Press.

Harrington, W., R. Morgenstern. & P. Nelson, 1999. *On the Accuracy of Regulatory Cost Estimates.* Resources for the Future, Discussion Paper 99-18 (January) (available at www.rff.org).

Hart, Stuart. 1997. *Beyond Greening: Strategies for a Sustainable World*, Harvard Business Review 66 (January/February 1997).

Holmstrom, B. & P. Milgrom, 1992. AMulti-Task Principal-Agent Analysis: Incentive Contract, Asset Ownership and Job Design,@ 7 *Journal of Law, Economics and Organization*

24.

Jaffee, A., S. Peterson, & P. Portney, 1995. *Environmental Regulation and the Competitiveness of U.S. Manufacturing: What does the Evidence Tell Us?* XXXIII Journal of Econ. Lit.132 (March).

International Bank for Reconstruction and Development, 1996. AIR POLLUTION FROM MOTOR VEHICLES: STANDARDS AND TECHNOLOGIES FOR CONTROLLING EMISSIONS. (Washington, D.C.)

The Management Institute for Environment and Business. 1996. COMPETITIVE IMPLICATIONS OF ENVIRONMENTAL REGULATION: A STUDY OF SIX INDUSTRIES (Washington, D.C.).

Meyer, S., 1993. ENVIRONMENTALISM AND ECONOMIC PROSPERITY (MIT, Cambridge, MA).

Morgenstern, R., W. Pizer & J. Shih, 1998. *The Cost of Environmental Protection*. Resources for the Future, Discussion Paper 98-36 (May) (available at www.rff.org).

National Academy of Sciences, 1995. ALLOCATING FEDERAL FUNDS FOR SCIENCE AND TECHNOLOGY. (Washington, D.C.)

National Academy of Sciences, 1991. POLICY IMPLICATIONS OF GREENHOUSE WARMING. (Washington, D.C.)

Nelson, Tietenberg and Donihue, 1993. Differential Environmental Regulation: Effects on Electric Utility Capital Turnover and Emissions. *Review of Economics and Statistics* 77(2), 368-373.

Organization for Economic Cooperation and Development, 1989. ENVIRONMENTAL POLICY BENEFITS: MONETARY VALUATION (Paris).

Pfaff, A.S.P., and C.W. Sanchirico (1998) *Environmental Self-Auditing: Setting the Proper Incentives for Discovering and Correcting Environmental Harm.* Working Paper, Department of Economics, Columbia University.

Porter, Michael & van der Linde, Claas, 1995a, Green and Competitive: Ending the Stalemate, Harvard Business Review, 120 (Sep-Oct 1995).

Porter, Michael & van der Linde, Claas, 1995b, Toward a New Conception of the Environmental-Competitiveness Relationship, J. Econ Perspectives (Fall 1995) pp. 97-118.

Portney, Paul, 1994, Does Environmental Policy Conflict with Economic Growth?, Resources (Spring 1994) pp. 21-23.

Rejeski, David, 1995. *The Forgotten Dimensions of Sustainable Development: Organizational Learning and Change*, 3 Corp. Envtl. Strategy 19 (Summer 1995).

Repetto, Robert, Environmental Productivity and Why it is so Important, 33 Challenge No. 5, 33-38 (Sept.-Oct. 1990). (utility sector social productivity + with envir.)

Roy, Manik, 1992. *Pollution Prevention, Organizational Culture, and Social Learning*, 22 Environmental Law 189.

Sarokin, D., W. Muir, C. Miller & S. Sperber, 1985, CUTTING CHEMICAL WASTES (INFORM, New York).

Simon, H.A. (1987) *Bounded Rationality*, in J. Eatwell, M. Milgate and P. Newman (eds), The New Palsgrave Dictionary of Economics, Vol. 1. Macmillan, London.

Sinclair-Desgagné, B. and H.L. Gabel, 1997. *Environmental Auditing in Management Systems and Public Policy.* Journal of Environmental Economics and Management 33:331-346.

Smart, Bruce, ed. 1992. BEYOND COMPLIANCE: A NEW INDUSTRY VIEW OF THE ENVIRONMENT. World Resources Institute, Washington, D.C.)

Strasser, Kurt, 1996. *Preventing Pollution*, VIII Fordham Environmental Law Journal 1-47 (Fall).

Strasser, Kurt, 1997. *Cleaner Technology, Pollution Prevention, and Environmental Regulation*, IX Fordham Environmental Law Journal 1-106 (Fall).

Stewart, Richard Environmental Regulation and International Competitiveness, 102 *Yale Law J.* 2039 (June 1993).

UCLA Pollution Prevention Education and Research Center, UCLA WET CLEANING DEMONSTRATION PROJECT, INTERIM PROGRESS REPORT (Univ. Calif at Los Angeles, Nov. 1, 1996).

U.S. Environmental Protection Agency, 1998. STAKEHOLDER ATTITUDES ON THE BARRIERS TO INNOVATIVE ENVIRONMENTAL TECHNOLOGIES. EPA 236-R-98-001.

U.S. Environmental Protection Agency, 1993. REMOVING BARRIERS AND PROVIDING INCENTIVE TO FOSTER TECHNOLOGY INNOVATION, ECONOMIC PRODUCTIVITY AND ENVIRONMENTAL PROTECTION. EPA 100-R-93-004 (April).

U.S. Environmental Protection Agency, 1992. FACILITY POLLUTION PREVENTION GUIDE. EPA 600-R-92-088.

U.S. Environmental Protection Agency, 1991. PERMITTING AND COMPLIANCE POLICY: BARRIERS TO U.S. ENVIRONMENTAL TECHNOLOGY INNOVATION. (EPA 101/N-91/001.

U.S. Environmental Protection Agency, 1990 ENVIRONMENTAL INVESTMENTS: THE COST OF A CLEAN ENVIRONMENT.

US Office of Technology Assessment, 1994. INDUSTRY, TECHNOLOGY, AND THE ENVIRONMENT: COMPETITIVE CHALLENGES AND BUSINESS OPPORTUNITIES. US GPO, Washington, D.C.

US Office of Technology Assessment, 1995. GAUGING CONTROL TECHNOLOGY AND REGULATORY IMPACT IN OCCUPATIONAL SAFETY AND HEALTH - AN APPRAISAL OF OSHA'S ANALYTIC APPROACH. (OTA-ENV-635) US GPO, Washington, D.C.

Utterback, James, 1994. MASTERING THE DYNAMICS OF INNOVATION.

Weitzman, Martin, 1994. *On the Environmental Discount Rate*. 26 J. Environ. Econ. Management 200 (March).

White House Office of Science and Technology Policy, 1994. TECHNOLOGY FOR A SUSTAINABLE FUTURE. (Washington, D.C.).

B. Summary of the Workshop on Innovation, Cost and Environmental Regulation

Help on April 30th, 1999
Resource and Conservation Center
Washington, D.C.

Co-sponsored by the
Environmental Law Institute and
Carnegie Mellon University

with the Support of the Economy and Environment Division, USEPA

Nearly 100 people filled conference rooms at the Resource and Conservation Center in Washington, D.C. to hear a research and policy update on expected compliance cost and innovation resulting from environmental regulation. The issue, popularized as the Porter Hypothesis, is whether tighter environmental regulation causes an industry to become more instead of less competitive in today's global economy.

David Rejeski of the Council on Environmental Quality opened the meeting by summarizing the intellectual history of the issue that from the first has seemed to pit skeptical economists against more receptive representatives of business. That division, with only modest middle ground, continues to the present. Mr. Rejeski identified several key issues to be addressed. What is the empirical evidence that there is a competitive penalty to regulation? If so, what does it look like? Are their certain behavioral and structural factors in firms and sectors that tend to mitigate the penalties? Is there a way to regulate that reduces competitive impacts, enhances environmental performance, and increases innovation? Mr. Rejeski concluded by challenging the workshop to produce a list of policy conclusions, research recommendations, and to determine whether a shift in perspective has occurred about the hypothesis.

Panel I: Perspectives on the Economic Costs of Environmental Regulation

Scott Farrow of the Center for the Study and Improvement of Regulation at Carnegie Mellon University moderated the first panel on studies of the costs impacts of environmental regulation. He pointed out that regulatory analysis is proceeding to a deeper examination of the linkages among regulatory design, organizational behavior and performance.

Professor Adam Jaffe of Brandeis University opened the discussion by surveying seven dimensions of competitiveness, including cost, balance of trade, foreign direct investment, plant location, innovation, productivity growth and economic growth. Updating earlier work, Jaffee noted that there was substantial agreement among economists that environmental regulation is likely to stimulate research, and that innovation may make regulation less costly. Overall, however, there remains little evidence to support either claims that environmental regulations causes either large adverse effects on competitiveness, or large positive impacts on innovation and competitiveness. He noted that some of the most recent econometric evidence indicated that regulation resulted in statistically significant but very small reductions in economic growth.

In concluding, Professor Jaffee proposed the "Jaffe Hypothesis" that second-order effects of regulation (good or bad) are small relative to first-order effects. This implies that measured costs are reasonably accurate, and that innovation does not make regulation free, just cheaper than industry says in advance. He further noted that despite the disagreement about the extent of innovation, there is widespread agreement that the current regulatory system uses inflexible mechanisms likely to stifle innovation and escalate costs. He proposed that instead of arguing about differences we focus on reforms that would replacing inflexible regulations with incentive-based approaches to make them less stifling or positively innovation-enhancing.

Professor Richard Florida of Carnegie Mellon University presented the results of a series of structured surveys and case studies carried out to assess the linkages between elements of green management, such as pollution prevention or environmental management systems, and innovation practices focused on company core capabilities. This research has found that companies that achieve innovative management and high levels of resource productivity are also the ones achieving positive environmental performance. Roughly 40% of companies in a field are leaders, whereas 15-20% are doing little. The green innovators tend to be larger, spend more on research and development, and in general are also innovators in their core business. They found a company's ability to innovation strongly mattered to all performance measures, as did its use of systems to measure results. Other major determinants of innovation were barriers and resource constraints, and not lack of information.

Professor Florida suggested that a problem with environmental regulation is that it treats all firms equally. A major policy recommendation would be to achieve more flexible regulations, that set standards but do not impose the remedy as the current system tends to. He endorsed the recommendation in the background paper, and noted he had repeatedly witnessed the problems caused by inflexible regulations within innovative firms. In a sense the current regulatory system penalizes the innovators and rewards the laggards. A forward-looking research agenda would stress a multi-disciplinary approach, and focus on environmentally conscious manufacturing. He expressed his hope that the government and foundations would fund research on this subject.

The morning session concluded with two presentations by Billy Pizer and Winston Harrington of Resources for the Future. Dr. Pizer presented statistical results for environmental costs borne by about 550 manufacturing plants observed over time. The results indicated that the impact of a reported dollar increase in environmental spending caused somewhat less than a dollar increase in total spending, or about 82 cents, due to cost-reducing offsets. There was considerable variety within industries, but at worst, environmental cost increases in an industry led to total cost increases of more than a dollar, but generally less than two dollars. He noted that the estimates of costs in their study would be much higher if they had not controlled for inter-plant differences. He felt this might explain why some other studies find very high environmental costs, as they do not control for such differences. While their study indicates that our present form of environmental regulation does impose costs, it indicates innovation to some extent offsets costs, and rejects the notion that environmental regulation causes dramatically escalating costs.

Winston Harrington concluded the morning session with a study of *ex-ante* and *ex-post* estimates of the cost of 25 specific federal regulations. Overall, their research found that *ex-ante* estimates tend to overstate both total costs and environmental efficacy, while estimates of costs per unit of reduction were about right. A variety of factors is believed responsible that includes innovation that reduces costs, but also other factors as the tendency for final regulations to be weaker than those proposed, when the cost estimates had been made. One of the interesting findings is that the implication of the Porter hypothesis hold true most strongly for the 7 regulations implementing market-based approaches. For these, the actual results showed that total and per-unit costs were consistently less than estimates, and environmental effectiveness greater, a much stronger correlation than for other types of regulation.

The audience, with members from industry, government, environmental groups, and trade associations, raised numerous questions throughout the presentations. No formal conclusions were drafted during the workshop though sentiment in the morning seemed to coalesce around the win-win returns from regulatory flexibility and innovation if other objectives can be met, the potential to distinguish different categories of those regulated, and remaining uncertainties in the links between specific regulatory designs, the response of industry, and various aspects of environmental, social, and economic performance.

Panel II: Incentives and Barriers to Innovation

Byron Swift of the Environmental Law Institute introduced the next panel, consisting of Prof. Kurt Strasser of the University of Connecticut Law School, Dr. Bernard Sinclair-Desgagné of the Inter-University Center for Research and Analysis of Organizations, and Robert Day of World Resources Institute. These panelists would attempt to identify the practical legal and organizational barriers that could prevent a firm from developing and implementing cost -effective pollution prevention solutions.

Mr. Swift noted that research done by ELI indicates that regulatory barriers constrain innovative and prevention-oriented approaches in the environmental field. These stem from the way environmental laws are written and enforced, and possibly more than fundamental economics explain why compliance costs may be high in some industries. In particular he noted that rate standards such as those based upon "achievable control technologies"cause significant problems as they restrain flexibility and lead to governmental review of technology choices. Wherever possible, such as for area-wide pollutants, these rate standard should be replaced by mass standards that are equally effective and much friendlier to innovation.

Kurt Strasser opened his remarks by posing the question why the current regulatory system has a marked preference for familiar technologies. He suggested one answer is that today's regulatory approach stresses a law enforcement mentality that grew out of legitimate public health concerns. His research reveals many causes for such a bias, especially in the permitting and enforcement process. Familiar technologies are readily evaluated by permit writers, and because they are, offer less delay to the company. The enforcement system also creates high risks to both permit writers and industry officers who support a new technology effort that may not attain its goals. In addition, the regulatory process creates monstrous records, and almost always generates a court case, reinforcing conservative decisions.

As a result, adopting new technologies has many risks, especially for process changes that may be environmentally preferable, but may change waste streams and so trigger the need for new permits. It usually takes time and occasional failures to make new technologies to work, and the inhospitality of our present regulatory system to this process is evidenced in the woefully small financial investment into development of new environmental technologies today.

In closing, Professor Strasser offered several pointers towards a robust technology policy. First, he would target incentives on those likely to do the innovating that are greater than economic incentives. Doing this requires an evaluation of (1) the industry context; (2) technology options for the whole industry, (3) firm specific factors such as were discussed by Dr. Florida, and (4) regulatory options. A second is to adopt a cross-media approach. This has been attempted in a few instances, most notably in the pulp and paper sector, but appears difficult under current air and water laws that operate in almost isolation. Finally, he noted that while innovative pilot programs were good, they seldom addressed root causes and rarely developed a life after the program's end.

Unfortunately, it appears that implementing such an agenda may require changes in existing law. If we were to reform our environmental laws, Professor Strasser urges a consideration of a regulatory structure that would proceed industry by industry instead of medium by medium. Possibly this could be started at the state level, such as through partnership grants.

Bernard Sinclair-Desgagné suggested there are three kinds of innovation; incremental innovation, which typically comprises the bulk of industrial innovation, innovation oriented towards risk reduction, and radical innovation. The most controversial aspect of the Porter principal is its assertion that regulations could create radical innovations that lead to net profits. As it is difficult to address this issue using traditional economics, another ways to investigate this assertion is to open up some of the filed's "black boxes", such as innovation or the management of the firm, his area of research.

His studies of the operations within firms revealed several instances why so-called "low hanging fruit" might be available with win-win characteristics. One rationale is provided by the principle-agent problem, in which incentives may be poorly designed. Low-hanging fruits can also derive from coordination failures within a firm, such as communications failures. His work with Landis Gabel investigates how a firm's production habits and routines may keep it from acting optimally. Firms attempt to maximize efficiency by promoting routines. Although this is a sensible and necessary approach, it can lead to the oversight of possible changes and to the kinds of win-win situations Porter predicts. By forcing a firm to reconsider its actual processes and re-engineer its existing routines, stricter environmental regulation might actually push firm to revise its procedures and bring it closer to an operating optimum.

This theory might suggest that re-engineering, defined as tracing down elementary inputs and bunching them back into better routines, may always deliver low-hanging fruits. However, there will be associated costs to do this, and there may be complementarities in the production process that require many changes once one is made. Therefore, firms may not implement such changes due to such complementarities or to higher cost than benefits, as well as from inertia generated by political factors within the firm or by management systems.

Dr. Sinclair concluded by suggesting research into the following policy elements:

1) the role of regulation to tackle inertia with a firm; such regulation should be crafted to fit the type of innovation that is pursued - incremental (low-hanging fruits), risk reducing or radical;

2) the governmental role in harmonizing practices and norms, such as support of audit procedures, environmental management strategies, as well imposing penalties for non-compliance.

3) the use of credible threats of regulation, such as in the European Community, where a governmental threat to adopt common emerging regulations may be quite credible.. The purpose here is to promote industry research into better solutions without giving them strict time frames which might force a more rapid but less innovative pollution control response.

Robert Day next discussed recent research by World Resources Institute that reveals several factors determine superior corporate performance. These included the regulatory structure, reinforcing what had been said so far on the need for stringent but flexible performance-based regulation; the structure of the industry; an understanding of the role of the pollutant within the industrial process; and an understanding of the investment life-cycle relevant to the pollutant in question.

Their work emphasized a business value model that identifies the reasons for business successes and failures. In this context Mr. Day emphasized the importance of radical innovation to firms. A study by INSEAD in France showed that 86% of innovation was incremental, and only 14% could be classified as radical, but that 38% of firm revenues and 61% of profits derived from those radical innovations. There are many current barriers though to achieving this model, such as the lack of entrepreneurship in the Environmental Health and Safety divisions of firms. Also, despite the evident attractiveness of market-based standards, some research has revealed existing firms may prefer the present regulatory system they have learned to live with.

In conclusion, his policy recommendations included: (a) emphasizing overall performance standards in government regulation; (b) collaborative development between government and industry; (c) an emphasis on management issues, and (d) identifying how non-governmental efforts could support a clean production agenda, such as the release of information on pollutants, certification and green labeling, and pressure imposed by buyer collaboratives.

C. Introduction to Workshop on Cost, Innovation and Environmental Regulation

By David Rejeski, Council on Environmental Quality

For over thirty years, a healthy debate has occurred in the United States and other industrialized countries over the costs and benefits of environmental regulations. Though this debate has had many nuances, one commonly held view is that regulatory-based environmental wins came at the cost of industry losses – losses characterized by increased costs of compliance, lost productivity or market share, and negative impacts to innovation. Though there were occasional reports of win-win projects in firms such as 3M, such events were rare and win-win examples became environmental policy's version of the Lock Ness monster -- more shrouded in myth than supported by substance. However, occasional events raised hopes that contrary to popular wisdom, regulation could spur innovation, enhance competitiveness, and more than offset the costs of compliance.

In 1991, a short essay by Michael Porter in *Scientific American* entitled "America's Green Strategy," helped raise the visibility of the debate. Porter was not the first to argue that regulations could result in win-win propositions for industry, but he was certainly the most visible, and his "hypothesis" provided a target that drew out the dissenters and supporters. In 1994, Noah Walley and Bradley Whitehead countered Porter in the *Harvard Business Review* with an article entitled "It's Not Easy Being Green." Fault lines began to appear between corporate managers and business school researchers, who tended to support Porter's hypothesis, and economists, many who felt that such win-win situations were rare and their benefits more than outweighed by the overall costs of regulatory compliance. The intellectual fisticuffs continued when Porter and van der Linde published "Green and Competitive: Ending the Stalemate," in *Harvard Business Review* in 1995. Unfortunately, the stalemate did continue and the article triggered another torrent of letters and more papers from various corporate and academic "camps" that had hardened their positions around the debate.

This would be just an interesting academic footnote if it were not so relevant to American business, our capacity for technological innovation, and the competitive position of U.S. industry in the $400 billion global marketplace for environmental goods and services. Amazingly, without knowing the answer to the fundamental issue that Porter raised, we have regulated industry for decades.

To re-examine the evidence surrounding the Porter hypothesis, the Environmental Law Institute and the Center for the Study and Improvement of Regulation at Carnegie Mellon University sponsored a one-day workshop on April 30, 1999, which brought together researchers from both sides of the debate. The papers that follow update our state of knowledge and attempt to provide answers and guidance in two important areas. First, does the existing body of research surrounding the Porter hypothesis allow us to regulate more effectively, i.e., in ways that reduce competitive impacts, enhance environmental performance, and increase innovation? Second, are there glaring knowledge gaps where additional research is needed as a prerequisite for better regulatory design?

It is important to keep in mind that Porter has presented us with more than a research hypothesis. At a more general level, it is a challenge to government institutions to pay attention to the dynamics of competition. Management guru Peter Drucker has pointed out that the theory of business has to be tested continually. The same is true of environmental policy, especially in a world where business practices are being continually restructured and our entire knowledge base doubles every seven years. Built into our regulatory organizations must be ways to systemically monitor and test the theory of regulation and the models of business upon which regulation is constructed. In the end, the theory and practice of environmental regulation must be constantly informed by the theory and practice of business. Here then, are the beginnings of that important conversation.

PART II

Panel 1: The Impact of regulation on Costs and Pollution

Moderator: Scott Farrow, Director, Center for the Study and Improvement of Regulation, Carnegie Mellon University

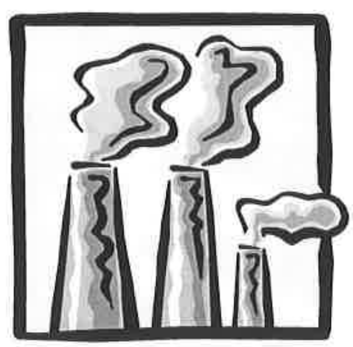
A. Environmental Regulation and Competitiveness: An Interpretive Update

Presentation by Adam Jaffee, Brandeis University

Environmental Regulation and Competitiveness: An Interpretive Update

Adam B. Jaffe, Brandeis University

ELI/CMU Forum
April 30, 1999



Competitiveness?

- Costs
- Balance of Trade
- Foreign Direct Investment
- Plant Location
- Innovation
- Productivity Growth
- Economic Growth

Jaffe, Peterson, Portney and Stavins, 1995

"Overall, there is relatively little evidence to support the hypothesis that environmental regulations have had a large adverse effect on competitiveness, however that elusive term is defined."

"... there is also little or no evidence supporting the revisionist hypothesis that regulation stimulates innovation and improved international competitiveness."

Generic Difficulties

- **Measuring stringency of regulation**
- **Endogeneity**
- **Left-out variables**
- **Unknown counterfactual**
- **Ideology**

Trade, FDI and Location

- Some evidence of effects for LDCs, but measures of regulatory stringency are problematic
  - Kolstad and Xing (air pollution)
  - Unteroberdörster (participation in treaties)
- New evidence on U.S. indicates modest negative impacts
  - Becker and Henderson on ozone
  - Greenstone on 4 criteria pollutants

Productivity

- Are "actual" costs more or less than reported PACE expenditures?
- Gray and Shadbegian--more (but left-out variables)
- Morgenstern, Pizer and Shih--less (but stay tuned)
- Berman and Lui --less (in L.A. oil refineries)
- Greenstone --more (implicitly, but a very small amount)

Economic Growth

- Michael Greenstone: best econometric evidence yet:
  - plant-level data for all of manufacturing
  - plants identified with counties and with industries, allowing very detailed controls for other drivers
  - exogenous measure of regulatory stringency: counties' CAA compliance status for each criteria pollutant
- Result: statistically significant but very small reductions in economic growth

The "win-win" debate: Areas of agreement

- Much existing environmental regulation uses inflexible mechanisms likely to stifle innovation.
- "Incentive-based" mechanisms are likely to be more conducive to innovation.
- Firms are boundedly rational so that external constraints can sometimes stimulate innovation that will leave the firm better off.

Areas of agreement (2)

- Environmental regulation is likely to stimulate R&D and other searches for less-polluting technology and processes. (Jaffe and Palmer)
- This is likely to result in innovation that makes the regulation less costly.
- Forecasts of compliance costs for new regulations are likely to be overstated.
- First-mover advantages may result from domestic regulation that correctly anticipates world-wide trends.

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Analytical/factual disagreements

- Widespread case-study evidence indicates significant "innovation offsets" are common.
- Innovation in response to regulation is evidence of offset.

- Case studies are highly selective. Firms believe regulation is costly.
- Even if cost-reducing innovation occurs, need to worry about "opportunity cost" of R&D and management effort.

Analytical/factual disagreements (2)

- Pollution is evidence of waste, suggesting reason why cost-reducing innovation in response to regulation might be the norm.
- Existing productivity or cost studies do not capture innovation offsets.

- Costs are costs; even if firms aren't at the frontier, side-effects of pollution reduction could just as easily be bad as good.
- Existing studies show that innovation offsets have been very small.

Analytical/factual disagreements (3)

- We have found a lot of evidence of innovation offsets even though existing regulations are badly designed. This suggests that offsets from good regulation would be large.
- Economics is Panglossian.

- Since you agree that bad regulations stifle innovation, the beneficial effects of existing regulation only shows that case studies are highly misleading.
- Economics is the dismal science.

The Jaffe Hypothesis®
(You heard it here first.)

- **Second-order effects (good or bad) are small relative to first-order effects.**
- **Implications:**
  - **Measured costs do not grossly understate *or* grossly overstate actual costs**
  - **Innovation does not make regulation free, just cheaper than industry says in advance (but you knew that already)**

Parting Thought

- We all agree that much existing regulation stifles innovation.
- Replacing inflexible regulations with incentive-based approaches would make regulation either less stifling or else positively innovation-enhancing.
- Why don't we focus on achieving this?

B. What Makes Companies Green? Organizational Capabilities and the Adoption of Environmental Innovations1

By Richard Florida, Heinz Professor of Economic Development, Heinz School of Public Policy and Management, Carnegie Mellon University [e-mail: florida@andrew.cmu.edu]

INTRODUCTION

The adoption of innovative environmental practices by industry is a subject of considerable interest to scholars concerned with the environment as well as by social scientists from a variety of disciplines. Environmental innovations are a special class of advanced business practices, referred to here as environmentally conscious manufacturing (ECM), which include practices such as source reduction, recycling, pollution prevention, and green product design. A number of studies have noted the adoption of ECM practices by industry [Florida 1996; Porter and Van der Linde 1995a, 1995b; Denton 1994; Office of Technology Assessment 1994; Makower 1993; North 1992; Office of Technology Assessment 1992; Schmidheiny 1992; Smart 1992], while others have examined the factors associated with adoption of these practices [Florida 1996; Atlas and Florida 1997]. A growing body of research argues that adoption of ECM practices can lead to improvements both in environmental outcomes and overall business performance [Porter and Van der Linde 1995a, 1995b; Hart and Ajhuba 1994]. This literature, however, is dominated by case studies which provide suggestive insights but from which is it is difficult to generalize. Furthermore, these studies tend to focus on the role of factors operating outside the boundaries of the firm, such as regulatory pressure

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1 This presentation is based on the paper by Richard Florida, Mark Atlas and Matt Cline. The authors wish to acknowledge that the research was supported by the National Science Foundation Division of Geography and Regional Science and Environmentally Conscious Manufacturing Program.

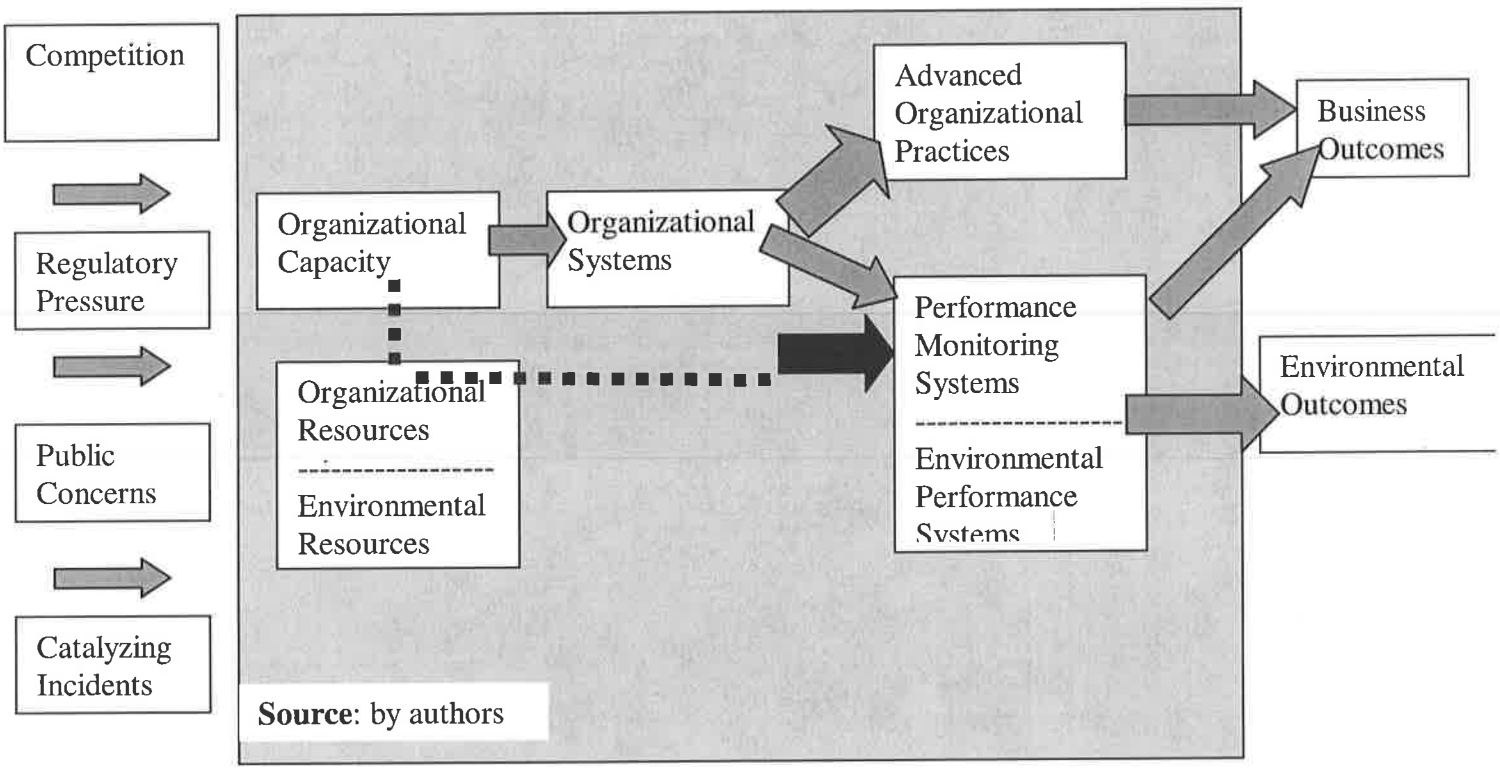
or market forces, in motivating firms to adopt environmental innovations.

Little, if any, empirical research has examined the way that factors operating inside the firm - organizational factors - effect the propensity to adopt ECM practices. Such factors are important, as both organizational theory and recent empirical research on the adoption of advanced business practices indicate that organizational factors matter significantly in the adoption of organizational innovations by firms. Recent studies focus on the role of "organizational capabilities" in both organizational innovation and organizational performance [Cohen and Levinthal 1994; Teece and Pisano 1994; Winter 1987]. This work suggests that organizations vary in their internal resource bases and procedures, which in turn affects their ability and opportunity to respond to internal and external challenges.

Building from this emergent literature on organizational capabilities, this paper focuses on the organizational factors associated with the adoption of ECM practices. It advances the hypothesis that organizational capabilities matter significantly in the adoption of ECM practices, and are thus likely to outweigh external factors, such as regulatory and market factors, that have been the primary focus of previous research. In advancing this hypothesis, we distinguish between several dimensions of organizational capabilities: organizational resources and capacity, organizational innovativeness, and organizational monitoring. Organizational resources and capacity refer to the level of overall level of resources and specialized environmental resources and capacities possessed by firms. Organizational innovativeness refers to firms' previous commitment and track record in implementing advanced organizational practices. Organizational monitoring refers to the methods by which organizations measure, analyze, and monitor their performance in key dimensions (in this case environmental performance and its relationship to overall business performance).

The research was designed both to assess the relative roles played by organizational versus external actors in the adoption of ECM innovations and to zero in on the functions of various dimensions of organizational capabilities in this process. To help structure our argument, a model of the interactions among external and organizational factors is presented in Figure 1. The model outlines the system of relationships between external (market and regulatory) factors and several dimensions of organizational capabilities.

Figure 1: Model of Organizational Factors, Organizational Systems, & Outcomes



We explore these questions and hypotheses through a structured field research study of a sample of manufacturing organizations. The research is based upon "matched pairs" of plants in several industries. It was conducted at 11 plants and consisted of more than 100 personal interviews.

The major findings of the research confirm the main hypothesis. The findings demonstrate that organizational capabilities matter significantly in the process of ECM adoption by sample plants. Furthermore, the research results indicate that two types of organizational capabilities are particularly significant to ECM adoption. First, organizational resources - particularly specialized environmental resources - provide the embedded capacity which enable sample plants to respond to external stimuli and implement environmental innovations. In effect, organizational resources create the opportunity space from which individual managers and work groups are able to experiment with and effectively implement ECM practices. Interestingly, the findings suggest a loose association between organizational innovativeness (measured as prior adoption of advanced business practices) and ECM adoption among sample plants. Second, the findings indicate that organizational monitoring systems play a crucial role in ECM adoption. The findings here suggest that in order for environmental gains to be realized, explicit objectives and monitoring systems are required to assess the relationship between dedicated organizational resources, innovative practices, and environmental and business impacts.

THEORY, CONCEPTS AND HYPOTHESES

Our main hypothesis, as noted above, is that internal organizational factors play a fundamental role in the ability of organizations to adopt advanced environmental practices. To better inform this conceptualization, we draw on three strands of recent research. First, we briefly review previous research on role of external factors (regulatory pressure and/or market forces) in shaping the adoption of advanced environmental practices. Second, we turn to recent studies of organizational factors in the adoption of advanced organizational practices (particularly innovative workplace practices) and related research on the role of "organizational capabilities" on firm performance. Third, we review recent literature on the role of organizational factors in the adoption of advanced environmental practices. We believe our conceptual approach offers a more synthetic perspective on what matters to the adoption of environmental practices in particular, and some general insights into the role of organizational factors in the adoption of advanced organizational practices more generally.

External factors and the adoption of environmental innovations: A growing body of studies note the adoption of environmentally conscious manufacturing (ECM) practices by industry [Florida 1996; Porter and Van der Linde 1995a, 1995b; Denton 1994; Office of Technology Assessment 1994; Makower 1993; North 1992; Office of Technology Assessment 1992; Schmidheiny 1992; Smart 1992]. This work has reinforced a significant shift in theorizing about the relationship between economic and environmental performance. Traditionally, the relationship between the economy and the environment was thought of in terms of a rather stark tradeoff. But, recent theorizing and some empirical research has questioned this view, suggesting that adoption of environmental innovations enable firms to overcome this dichotomy. A number of studies have argued that corporate efforts to implement ECM practices are part of broader strategies to improve overall business performance as well as environmental outcomes. One influential argument, associated principally with Porter [1991], contends that the pressure to innovate stems from regulatory pressure, as firms respond in creative and dynamic ways to environmental regulation by introducing innovations which improve environmental outcomes.

Other studies argue that environmental innovation is the result of market pressures that cause firms to become more efficient. These studies are important because they have shifted attention away from simple regulatory compliance and toward factors which contribute to environmental innovation. Several studies note that practices which improve facilities' overall efficiency can be applied to environmental management to reduce the toxicity and/or amount of wastes generated, thereby lowering the environmental risks resulting from production operation. A study by Porter and van der Linde [1995a, 1995b] concluded that firms respond to competitive conditions and regulatory pressure by developing strategies to maximize "resource productivity", enabling them to simultaneously improve their industrial and environmental performance [1995a]. A statistical study by Hart and Ahujba [1994] found that efforts to prevent pollution and reduce emissions had a positive effect on industrial performance. This study also found that the biggest benefits accrued to large polluters, noting that the closer a firm came to zero emissions the more expensive it was to further reduce pollution or realize efficiency or performance gains.

This body of research is important in that it has helped recast the debate over environmental and business outcomes and began to focus attention on the adoption of environmental innovations. However, this work suffers from two general kinds of problems. One the one hand, virtually all of it has neglected the potential role played by organizational factors operating inside firms. On the other hand, the great majority of studies take the form of selective case studies, which represent "success stories," thus leaving the external validity of results open to question.

Organizational innovation: There is a long and distinguished literature on the adoption of organizational innovations and the factors associated with adoption of innovative practices. For our purposes here, it is useful to focus on recent theorizing on the role of organizational capabilities in shaping firm performance. These studies take issue with traditional economic approaches and argue that firms possess different bundles of organizational capabilities that can lead to differential performance.

There is a considerable literature on the recent adoption of organizational innovations by firms. These organizational innovations are sometimes referred to under rubrics such as "lean production," "agile manufacturing," and "high-performance work systems" [see for example Womack, Jones and Roos 1990; Osterman 1994]. According to this perspective, organizational innovations are conceived as interrelated bundles or systems of practices (e.g. self-directed work teams, worker rotation, total quality management, and continuous process improvement). Osterman [1994] found a significant rate of adoption of innovative workplace practices across a wide sample of U.S. business establishments. Other studies have examined the factors associated with the adoption and diffusion of such organizational innovations. Florida and Jenkins [1998; Jenkins and Florida 1998] found that the adoption of such organizational practices by a sample of Japanese-owned manufacturing "transplants" in the United States was associated with factors such as capital intensity and in industries which are distinguished by tight end-user supplier relations. Several significant studies have probed the relationship between innovative practices and firm performance. MacDuffie [1994] identified performance gains associated with adoption of lean production in a large international sample of automotive assembly plants, while Ichniowski, Shaw, and Prennushi [1993] found significant performance gains associated with the adoption of a bundle of innovative manufacturing and work organization practices in the steel finishing sector.

These studies provide a window into the role of organizational capabilities in the adoption of innovative practices and in assessing their effect on organizational performance. Our research applies insights culled from this work to examine how organizational factors effect the adoption of innovative ECM practices.

Organizational factors and environmental innovation: There is a growing literature on the adoption of environmental innovations by firms and the factors associated with such adoption. Recent studies note the relevance of organizational factors to the adoption of environmental innovations [Apaiwongse 1995; Georg, Ropke and Jorgensen 1992; Gladwin 1992; Green, McMeekin and Irwin 1994; Groenewegen and Vergragt 1991; Kemp, Olsthoorn, Oosterhuis and Verbruggen 1992; Lawrence and Morell 1995; Post and Altman 1992; Schot 1992; Winn 1995; Winn and Roome 1993]. Some studies note similarities in the factors associated with the adoption of environmental innovations and advanced organizational systems and practices. An MIT study of several automotive factories identified a relationship between innovative production practices and ECM adoption [Maxwell, Rothenberg and Schenck 1993]. Another study found that organizations with a "team-orientation" were more likely to voluntarily adopt environmentally beneficial policies [Apaiwongse 1995]. A field research study of U.S. chemical companies concluded that higher performing environmental companies tended to have explicit objectives, long-range planning, performance-based evaluations, pro-active corporate cultures, formalized control, measurement and reward programs [Dillon and Fischer 1992]. In a comparative examination of environmental policy in Europe, the United States and Japan, Wallace concluded that the pursuit of both radical technological innovation and continuous incremental improvements in products and processes (e.g. kaizen) created substantial opportunities for pollution prevention and waste and emissions reduction. A 1994 CMU survey examined the factors associated with ECM adoption through survey research on national sample of U.S. corporations [Florida 1996]. The CMU study found that nearly half of survey respondents had implemented a "total quality environmental management system," similar to the total quality management programs used more general in manufacturing settings. Nearly two-thirds of survey respondents reported that line workers were key contributors to pollution prevention efforts - the same type of worker involvement that distinguished advanced manufacturing systems more generally. A survey research study [Atlas and Florida 1997] found that organizational factors play an important role in the adoption of green design.

Other studies note an association between ECM adoption and supply chain innovations of the sort that characterize advanced production systems. George, Ropke Jorgensen [1992] found that the adoption of pollution prevention was associated with tight linkages and interactions across the chain of production - that is among plants, their suppliers and customers - a finding which is in line with the findings of research on the adoption of advanced production systems [esp. Florida and Jenkins 1998; Jenkins and Florida 1998]. A study [Schot 1992] of multinational corporations found that interactions with suppliers as well as just-in-time inventories, were key factors in the adoption of environmental innovations. A survey of British companies [Green, McMeekin and Irwin 1994] found that the most important requirements for projects resulting in environmentally friendly products were collaboration with customers and suppliers that the quality of interaction processes between plants, suppliers and customers. The CMU survey found that half of survey respondents identified suppliers as key contributors to pollution prevention efforts [Florida 1996].

RESEARCH DESIGN

Building from these three strands of literature, we advance the hypothesis that organizational factors play a significant role in the adoption of environmental innovations. We pose this hypothesis in contradistinction to the prevailing view in the literature - and to some degree in both the conventional wisdom and prevailing approaches to public policy - which emphasizes the role of political (regulatory) factors and market forces in motivating ECM adoption. We draw from the literature on organizational capabilities to inform our perspective. Specifically, we argue that internal organizational capabilities play a large and significant role in the adoption of environmental innovations in particular (and in the more general process of organizational innovation broadly construed). We distinguish among three dimensions of organizational capabilities: organizational resources, organizational innovativeness, and organizational monitoring.

A structured field research design was developed to test these hypotheses and shed light on the factors associated with ECM adoption. Before proceeding to a detailed description of the field research, it is useful to highlight the key principles underlying our methodology. The research design took into account recent advances in the design of field research or qualitative research [King, Keohane and Verba 1994]. In the past, qualitative research in the social sciences has been subject to criticism on the grounds of external validity. The basic line of criticism contends that such research suffers from small sample sizes, which are biased and thus generate findings from which it is hard to generalize. While such criticisms are valid to some degree, they tend to conflate small sample sizes with inadequate sampling procedures and sample selection. A great deal of qualitative research in the social sciences suffers not from small sample sizes per se, but from problematic sample selection (e.g., "success stories" or convenience and snow-ball sampling). Recent advances in sample selection techniques make it possible to structure qualitative research designs in ways that generate samples that are much more reliable and thus generate externally valid findings.

Sample design and selection: The objective of the research was to better understand the processes by which some organizations adopt environmental innovations, while others do not. We thus designed the sample along the lines of a quasi-experimental design, with ECM practices constituting the intervention to be examined. We selected matched pairs of plants composed of high- and low-adopters of ECM practices. The high-adopters represent the experimental group, while the low- adopters represent the control group. Some might criticize this approach as sampling on the dependent variable. Recall however that qualitative research is time and resource intensive and that sample sizes are small. Focusing on a randomly distributed sample would in all likelihood overlook organizations at the extremes of the distribution - that is, organizations which represent a considerable degree of the variance in the population. Our strategy was to try to recreate this variance in our sample. Furthermore, guiding our sampling strategy was the belief that real analytical leverage could be gained into organizational factors by focusing on organizations at the extremes of the distribution - those with a special propensity to adopt ECM practices and those with a special propensity to ignore them. By focussing on organizations at the ends of the spectrum of adoption, we sought to be better able to assess what factors facilitated or obstructed ECM adoption. In order to control the effects of industry (technology and process differences) on ECM adoption, we selected matched pairs of plants in several types of industries where different patterns of adoption and different environmental practices might be expected: process industries, complex assembly industries, and fabrication industries. Within these constraints, we also sought to obtain a diverse sample of plants with respect to size and geographical location.

We used several techniques to identify matched pairs of sample plants. First, we used available data from the U.S. Environmental Protection Agency to identify ECM adopters. Here, we used the EPA "Envirosense" database which includes information on pollution prevention and other ECM practices. A search of this database identified 184 plants with high-observed ECM adoption. We also sought to focus our research on plants which utilized ECM practices to address relatively large waste streams and emissions. To do so, we examined EPA data on environmental outcomes for the 184 plants. This included EPA data on hazardous waste generation (from the EPA's Biennial Reporting System - BRS) and on toxic releases (from the EPA's Toxic Release Inventory - TRI). Of the total 184 plants, 114 were identified in the BRS data and 36 were identified in the TRI data. These 150 surviving plants were then separated into groups in the same industries, assigned on the basis of four digit SIC code. Each plant was rated on the extent of ECM adoption and BRS and TRI data on source reduction and recycling. Low-adopters were also identified using BRS and TRI data. We identified plants that did not report source reduction or recycling activities in the BRS and TRI data in the same SIC codes as high-adopter plants. We excluded plants with relatively small amounts of wastes or chemicals. EPA data were checked to ensure that these facilities had not reported in engaging in pollution prevention activities.

This process identified potential matched pairs of plants in the following industries: industrial organic chemicals (SIC 2869), electroplating (SIC 3471), automotive parts (SIC 3714), aircraft parts (SIC 3728), turbines (SIC 3511), and high speed drives and gears (SIC 3566). The procedure ultimately yielded a sampling frame of 17 plants from which we sought to identify four matched pairs of plants (n=8). We contacted the 17 plants and 11 agreed to participate in the study. It was decided to include all 11 plants in the study. The sample included 3 plants in the aircraft industry (two high-adopters and one low-adopter), three plants in the chemical industry (two high-adopters and one low-adopter), two plants in the electroplating industry (a high- and a low-adopter), and three other plants (two high-adopters and a low-adopter). The geographic distribution of sample plants was as follows: California (n=3), Alabama (n=2), Louisiana (n=2), Connecticut, Michigan, Pennsylvania and Texas (n=1, each).

Field research: Field research consisting of one or two day site visits and personal interviews were conducted with the 11 sample plants. The field research collected detailed information on the role of organizational factors in ECM adoption. The site visits and interviews obtained data on factors such as organizational characteristics and resources, business and management practices, environmental management practices, performance monitoring systems, and environmental and business outcomes, as well as regulatory compliance, market and competitive conditions and other external factors. More than 100 personal interviews were conducted with plant managers, production operations, environmental staff, financial affairs, supply and procurement, human resource representatives and production workers. A structured field research instrument was developed for conducting interviews for each of these groups of informants. Detailed notes were taken and each of the field research visits was written up as a case study, (For a fuller description of the research design, copies of the research instruments and summaries of the field research for each facility, see Florida and Atlas 1997).

To gain deeper insight into the process of ECM adoption, a rating or scoring system was developed for key variables and indicators, including: organizational resources, dedicated environmental resources, advanced business management practices, environmental monitoring systems and several other measures. The following specific measures were employed.

Organizational resources: facility size (number of employees), company size (number of employees).

Environmental resources: number, tenure, and experience of dedicated environmental staff.

Business practices: ISO certification, mission statements, formalized quality management systems, just in time inventory control, cross-functional resources, and problem-solving teams.

Environmental monitoring and systems: quantified environmental goals and objectives, environmental performance monitoring systems, environmental cost identification, use of control processes, environmental inspections and environmental supplier audits.

To operationalize these measures, we ranked interview responses for these indicators on a 6 point scale where 5 equals the highest value, and 0 the lowest.

STUDY FINDINGS

We now report the research findings. Generally speaking, the findings support the hypothesis that organizational capabilities matter significantly in the adoption of ECM practices. We find that external factors are insufficient to explain the variation in ECM adoption, and that organizational factors provide more explanatory power. To presage and orient the discussion which follows, Table 1 presents the overall scores and for the major variables in the analysis.

As these data show, the findings are robust with plants in the high-adopter sample scoring considerably higher overall in terms of organizational factors than plants in the low-adopter sample. The average overall score for high-adopter plants was 3.88 compared to 2.88 for low-adopter plants. This result is statistically significant at the .05 level in a two-tailed test, providing considerable confidence that it is robust. Furthermore, much of the same pattern holds for three of the four major organizational factors in the analysis: organizational resources, environmental resources, and environmental performance and monitoring systems. In each of these categories, there is a considerable difference in the scores for the two groups of plants, though the level of statistical significance varies. Environmental resources show the highest level of statistical significance (.01 level two-tailed test), followed by organizational performance ad monitoring systems (.05 level, two-tailed test), and organizational resources (.10 level, two-tailed test). The result for advanced business practices is not statistically significant; this variable appears to have virtually no role in ECM adoption by sample plants. The following sections elaborate on these findings, by providing a detailed discussion of the field research findings in each of these categories.

TABLE 1. Organizational Factor Scores for Sample Plants

FACTOR	High Adopters (N=7)	Low Adopters (N=4)
Organization Resources	4.43*	2.25*
Environmental Resources	4.62***	2.25***
Advanced Business Practices	3.1	3.13
Advanced Business Practices (w/o ISO 9000)	3.4	2.75
Environmental Metrics and Monitoring Systems	3.37**	1.5**

Overall Score	3.88**	2.28**

Source: by authors

* Significant at the .10 level, two-tailed test

** Significant at the .05 level, two-tailed test

*** Significant at the .01 level, two-tailed test

EXTERNAL FACTORS

We begin by briefly reviewing the field research findings with regard to the role of external factors - regulatory and market pressures - in ECM adoption. Here, we find that both play a role, but that this role is mediated by organizational factors (discussed below).

Regulatory pressure: The study findings with regard to regulation are mixed, suggesting that regulations play a mixed role in the adoption of environmental innovation. They stimulate some firms to adopt innovations, motivate others to comply, and take the form of barriers to still others. First, virtually all sample plants noted the motivation to comply with existing environmental regulations. Second, our findings provide some support for the Porter hypothesis. Sample plants - particularly plants in the high-adopter sample - noted that the fear of potential liabilities from sending wastes off-site for disposal motivated them to engage in pollution prevention, on-site treatment or disposal, or off-site recycling. Furthermore, large regulatory penalties functioned at times as "catalyzing incidents" which spurred sample plants to adopt ECM practices (discussed in the section on catalyzing incidents below). Third, a number of plants in the sample noted that environmental regulations form a barrier to adoption of ECM practices. This was particularly true of plants in the high-adopter sample. Several plants in the high-adopter sample expressed dissatisfaction with the apparent irrationality or relevance of some environmental requirements. One high-adopter plant, for example, reported that the threshold for reporting spills for some chemicals was lower than what ordinary people spill in the exposed environment. Sample plants also noted that some environmental agency personnel appear motivated by desire to find violations, even if they are unintentional and inconsequential, rather than to predict and prevent potential problems or to propose pollution prevention solutions. A number of sample plants reported the perception that environmental agency personnel were inadequately trained to assess significant violations or to offer advice on how to address potential problems. Sample plants noted that the failure to receive accurate, timely, and understandable information on environmental requirements from regulatory sources posed a considerable barrier to ECM adoption. One high-adopter plant reported this as a direct and substantial barrier, indicating that plant management was not willing to participate in government technical assistance programs for fear that this would lead to greater regulatory scrutiny.

Market forces and cost reduction: Our findings indicate that sample plants are motivated to reduce wastes and emissions in response to market forces, particularly as part of a broader strategy to reduce overall costs and realize long-run efficiencies and cost-savings. Our field research findings clearly support the view that organizations frequently adopt environmental innovations primarily to reduce costs or improve their production processes, as opposed to some altruistic concern for the environment. Not surprisingly, the field research indicates that market signals work inside as well as outside the factory: setting lower financial return thresholds for approving environmentally beneficial projects encourages ECM adoption.

Interestingly, however, we found sample plants frequently adopted practices that had substantial environmental benefits as part of a more general strategy to improve plant performance and productivity. In these cases, environmental improvement was the fortuitous byproduct of changes accomplished to reduce other (non-environmental) costs or to improve productivity or plant performance in general. One high-adopter plant reported that it introduced a new procedure for removing paint from its product (airplanes) without chemicals. While the primary reason for this innovation was to reduce the time involved in this production task, it also substantially reduced chemical use and emissions. Another high-adopter plant in the sample sought to improve costs and efficiency by recycling its scrap materials. Similar indirect environmental outcomes were reported at a number of low-adopter plants as well.

Here, the field research findings suggest that the existent literature may place too much emphasis on the direct relationship between cost reduction and adoption of environmental innovations. While our findings suggest that environmental innovation does at times occur as part of a long-run cost calculus, it is the indirect environmental outcomes that stem from more general efforts to improve efficiency, increase productivity and reduce costs that are increasingly important (and which have been by and large neglected in the literature).

Catalyzing incidents: Our field research uncovered a third type of external factor - which we refer to as "catalyzing incidents" - as playing an important role in the adoption of ECM practices. Catalyzing incidents refer to incidents which spur a plant to dramatically alter its approach to environmental considerations. We found that catalyzing incidents can take on a variety of forms such as, chemical spills, government enforcement, and new reporting requirements. Our fieldwork indicates that such incidents generated substantial adverse consequences for sample plants such as negative publicity, community hostility and large penalties. These incidents were "catalyzing" in that adverse consequences caused sample plants to reevaluate and improve their extant approaches to environmental issues and as such to facilitate and accelerate the process of ECM adoption. Furthermore, we found that even less serious events can function as catalyzing incidents if they occurred during a period when adverse economic performance caused sample plants to reevaluate their overall operations and business practices. This was particularly true of high-adopter plants in the sample. Our field research findings indicate that catalyzing incidents appear to have played a significant role in ECM adoption at 4 of 7 high-adopter plants. One high-adopter plant responded to a large chemical spill, while two others responded to fines for non-compliance. Only one low-adopter facility reported a significant catalyzing incident. At this plant, corporate level management became more proactive about environmental issues as a result of a multi-million dollar penalty incurred by several of its facilities. In short, we found that significant shock can trigger substantial improvement in the ways plants approach environmental considerations.

To summarize: the findings indicate that external factors play a role in motivating plants to adopt ECM practices. But, we suggest that external factors alone provide an insufficient explanation of the factors associated with the adoption or environmental innovations. It is our contention that a more thorough explanation rests on organizational factors.

ORGANIZATIONAL CAPABILITIES

We now turn our attention to the role played by those organizational factors in ECM adoption. Here, we advance the hypothesis that organizational capabilities shape and motivate the processes by which organizations adopt environmental innovations. These organizational factors are the mechanisms by which firms respond - effectively or ineffectively - to stimuli originating in the external environment. In particular, we focus on the role of organizational capabilities. We examine several dimensions of organizational capabilities: organizational resources (including a specialized class of environmental resources), organizational innovativeness (measured as prior adoption of advanced business practices), and organizational monitoring systems (quantitative goals and measurement systems). The subsequent sections present our key findings with regard to each of these factors.

Organizational resources: Our first measure of organizational capability is organizational resources. One of our central hypotheses is that organizational resources play an important role in ECM adoption. Organizations with greater resources possess the financial and human resources required to bear the costs associated with environmental and overall business improvement. To operationalize the construct of organizational resources, we use measures of plant size, size of corporate parent, and size of environmental staff as well as a series of more qualitative measures. The data for sample plants on these dimensions of organizational resources are presented at the top of Table 1.

As these data show, organizational resources appear to be closely associated with ECM adoption. The overall score for high-adopter plants on this measure is 4.43 compared to 2.25 for low-adopters. This result is significant at the .10 level (two-tailed test), providing a modest level of confidence in its robustness. This result appears to be driven by plant size, where the result is significant at the .05 level (two-tailed test); in contrast, the result for company size is not statistically significant. Thus, we find that ECM practices are closely related to plant size.

This point is reinforced by a closer look at the findings for individual plants. There is a clear resource differential between the two groups of plants. On the one hand, all but one of the plants (plant D) in the high-adopter sample are large plants, as measured by both plant and company size.

On the other hand, all of the plants in the low-adopter sample (plant C) are small to medium-sized plants and only one is related to a large corporate parent. Furthermore, it is important to point out that these two "outlier" plants have overall scores which deviate considerably from the other plants in their sub-samples. Specifically, the overall score for the one small facility /small company high adopter plant (plant D) is much lower (0.9) than that for the other plants in the high-adopter sample (average of 3.55). The overall score for the one plant in the low adopter sample which is a division of a large company (plant C) is much higher (3.35) than the average for the low-adopter group (2.05). This reinforces the point that the level of organizational resources has a significant effect on ECM adoption.

The logic underpinning these findings regarding the relationship between organizational resources and ECM adoption can be elaborated as follows. Larger plants possess greater resources which can be devoted to environmental innovation. Smaller plants - particularly those which are subsidiaries of small companies - encounter greater resource constraints. In such cases, resources are more likely to be devoted to core business endeavors (such as "getting product out the door") leaving insufficient resources to adequately address environmental innovation. Consequently, these plants lag on this dimension.

The field research reveals a variety of additional findings in terms of organizational resources. First, it appears that the relationship between corporate and plant level management can be important. The availability of corporate level resources may also play supportive role here, even though the general result is not statistically significant. Looking at the field research results for individual plants we find that corporate level may affect the process of ECM adoption in two ways. On the one hand, we find that the explicit commitment of top corporate management ECM practices provides leverage and support for local managers to promote ECM adoption. On the other hand, we find that lack of support - and in particular failure of corporate level managers to provide requested assistance in developing and implementing ECM practices - is a significant barrier to the adoption of environmental innovations at the plant level.

Environmental resources: Environmental resources are a specialized form of organizational capability. These comprise dedicated resources devoted to the environment. We operationalize environmental resources as follows: size of environmental staff, tenure of environmental staff, and other related measures [see Table 1 above].

Generally speaking, we find that environmental resources play a significant role in the adoption of environmental innovations, as the data in Table 1 show. The overall score for high-adopter plants is 4.6 compared to an overall score of 2.25 for low-adopters. This result exhibits a very high degree of statistical significance (.01 level, two-tailed test), providing confidence that it is influential and robust. Furthermore, the results for all of the individual variables in this category of environmental resources are statistically significant. For two of these variables - environmental staff and environmental staff experience - the results are significant at the .01 level, providing considerable confidence that they are robust; for environmental staff tenure, the result is significant at the .10 level.

In addition to this, the field research data reveal several more specific findings. First, environmental staff appears to be positively associated with ECM adoption. The high-adopter plants had significantly larger environmental staffs than low-adopters. All of the high-adopter plants had dedicated environmental staff, ranging from several to nearly 50. High-adopter plants were also able to leverage significant environmental staffs of their corporate parents. In contrast, low-adopter plants had an average of roughly one dedicated environmental staff person and few, if any, corporate environmental resources to leverage.

Second, we find that tenure and experience of environmental staff are positively associated with ECM adoption. The average tenure for environmental managers in high-adopter plants was more than 10 years (with some plants averaging 20 years). The average tenure of environmental managers at low-adopter plants was significantly lower, ranging from 3 to 7 years with some managers working on a part-time basis.

Third, we find that individual managers can act in a proactive and innovative fashion to facilitate ECM adoption. Several plants reported that managers, particularly environmental managers, acted at times "on their own" to implement, champion of spearhead adoption of innovative ECM practices. The concept of organizational capacity provides a useful way to contextualize these individual actions and behaviors. Every organization possesses a distribution of individuals who can undertake innovative behaviors. Organizations with greater capacity - and in this case greater specialized environmental capacity - will possess more individuals who are likely to undertake innovative behaviors, thus increasing the probability that individual action will result in adoption of innovative practices. Furthermore, as we will see, ECM adoption is associated with explicit goals, objectives and measurements that act as additional motivating forces on individual behavior.

Taken together, these findings lead us to conclude that environmental resources or capacity are important because of the specialized type of expertise or capability it mobilizes - the ability to formulate and implement environmental strategies. Access to human capital with specialized environmental expertise is important in identifying, implementing, and monitoring ECM practices. Due to the complexity of environmental law, such expertise is important in understanding the legal implications of possible changes and production process inputs and outputs. Furthermore, our findings indicate that environmental managers can act in a proactive way to facilitate adoption of environmental innovations, even in the initial or continued absence of noteworthy overall facility or corporate support.

Advanced business practices and ECM adoption: We now turn to the relationship between ECM adoption and the adoption of advanced business practices more generally. Previous research has pointed to an association between advanced business practices and the adoption of innovative ECM techniques. The reasoning here is straightforward: plants which adopt innovative business practices in general are more likely to be pre-disposed to adopting environmental innovations. The third section of Table 1 presents the relevant field research data for a range of advanced business practices, including total quality management, ISO 9000 certification, and just-in-time inventory control.

As these data show, there is at best a loose association between the adoption of advanced business practices and the adoption of ECM practices. There is virtually no difference in the overall score on this factor for high- and low-adopter plants and the result is not statistically significant. There is just one category - total quality management - where the result is significant 3.57 versus 1.25. (statistically significant at the .05 level). Interestingly, plants in the low-adopter group outscored plants in the high-adopter group in three of seven categories: ISO certification (5.0 versus 1.43, significant at the .10 level), just-in-time inventory control (3.75 versus 3.29), and cross-functional work teams (3.25 versus 2.57). Particularly surprising was the finding for ISO 9000 certification, where the result is counter-intuitive. Only one high-adopter plant reported that it was ISO 9000 certified, compared to all plants in the low-adopter sample. Despite this, we observe a relatively high rate of adoption of advanced business practices across the entire sample, particularly for the two categories of work teams, just-in-time inventory control, and mission statements. While it is possible that the results here are anomalous and/or artifacts of our sample, we conclude that it is more likely that the mixed findings with regard to advanced business practices reflect the increasingly widespread adoption of at least some aspects of advanced business practices by U.S. manufacturing establishments.

ECM adoption on the shopfloor: A considerable body of research on innovative work practices has focussed on the importance of involving shopfloor workers in work system innovations. A number of studies highlight the importance of production worker capabilities in both the adoption of and performance payback from innovative work practices. Careful empirical research on both the steel industry and the automotive industries have found that innovative work practices are most effective when they effectively mobilize the broad capabilities of production workers [Osterman 1994; Ichniowski, Shaw and Prennushi 1993; MacDuffie 1994; Florida and Jenkins 1998; Jenkins and Florida 1998].

The fieldwork yielded several interesting insights on the role of shopfloor workers in environmental innovation. First and foremost, plants across the entire sample reported the involvement of line workers to be of considerable importance to the adoption of ECM practices. A high-adopter plant reported that production workers are motivated to adopt ECM practices because the plant's team-based organization makes them responsible for environmental concerns in their area, such as noticing and reporting actual or potential chemical releases.

Second, plants across the entire sample reported that shopfloor workers are the source of many simple improvements, such as installing drip pans that cumulatively result in significant environmental gains. Sample plants reported that such improvements were obvious to line workers and that workers were frequently able to implement them. This was true of both high- and low-adopters. One high-adopter plant reported considerable gains in environmental performance as a result of such small scale, "common sense" improvements by production workers. The plant reported that such worker-initiated improvements accounted for some two-thirds of its environmental performance improvement. Another high-adopter reported that line workers developed a simple process for separating waste shavings from different metals, enabling the plant to sell these wastes at a greater return. A low-adopter plant indicated that "all" of its environmental innovations originated from production workers.

The field research data also indicate that workplace incentives play a significant role in this process. Sample plants reported that including environmental performance as part of workers' and facilities' overall performance evaluations tended to sensitize them to the benefits of engaging in environmental improvement. Sample plants also reported that line workers were more receptive to environmental requirements when the purposes behind them were made clear. Furthermore, the findings identified an interesting relationship between the adoption of ECM practices and worker-initiated environmental improvements. We found that sample plants which had adopted ECM practices were more likely to communicate their environmental objectives and progress to their workers. Plants in the sample reported the use of bulletin boards, newsletters, presentations, meetings and videos to communicate environmental objectives. All of the high-adopter plants utilized these forms of communication, while all but one of the low-adopter plants did not. Several high-adopter plants had formal policies on the environment and well-developed mechanisms to communicate those strategies to workers. Here, it appears that instituting formal environmental policies and communicating goals and objectives to workers have the effect of attuning and aligning workers with plant and corporate wide goals.

<u>Organizational monitoring</u>: Monitoring is a special type of organizational capability, that refers to the ability of an organization to measure, assess, and track performance in key areas. To operationalize the construct of organizational monitoring, we collected data on what we refer to as environmental systems and monitoring – that is, the use of explicit environmental objectives, environmental performance monitoring systems, environmental costs identification, and internal environmental audits. The relevant results are presented in the last section of Table 1.

The findings here confirm that ECM adoption is closely associated with organizational monitoring. High-adopter plants outscored low-adopter plants by a score of 3.37 versus 1.5, and the result is statistically significant (.05 level, two-tailed test). Furthermore, this result appears to be driven by two or three key variables: environmental goals and objectives (significant at the .05 level) and environmental performance monitoring systems (significant at the .05 level), and to a lesser degree by chemical control processes (significant at the .10 level). The results for the four remaining variables are not statistically significant: providing environmental information to workers, identification of environmental costs, environmental inspections and environmental audits of suppliers.

Further insight into this process can be obtained from looking at the field research findings in more detail. Here, a number of interesting findings emerge. First, the field research indicates that setting explicit quantitative goals for environmental improvement is closely associated with ECM adoption. Five of 6 high-adopter plants set explicit goals for waste and emission reduction, while only one low-adopter had done so. At two of these high-adopter plants, such goals were set at the corporate level and then implemented at the plant level.

Second, the field research demonstrates that the use of environmental performance systems for measuring progress toward goals is closely associated with ECM adoption. Environmental measurement systems appear to be an important tool for measuring results, determining progress, evaluating the effectiveness of alternative projects, motivating new initiatives, and identifying opportunities for ECM practices. One of the plants in the high-adopter sample developed systems to track environmental costs back to specific operations. This resulted, among other things, in increased sensitivity to pollution prevention opportunities. Many of the plants in the low-adopter sample simply included environmental costs in the general overhead category. Under such systems, environmental costs are allocated over all work through the common overhead rate, rather than being charged the particular operations or work that generated those costs.

A significant number of high-adopter plants reported utilizing systems to track chemicals and other materials. One high-adopter plant developed a system to track any spill or accident and to disseminate reports on them. While most of these events were trivial and did not have to be legally reported, the plant reported that the system functioned as a "learning device" and encouraged preventive measures. Another high-adopter plant reported that it records every environmental incident and conducts a root cause analysis. A third high-adopter plant reported that it developed a control system for all chemicals, requiring containers to be checked from centralized locations. This enabled the plant to closely track and monitor chemical use.

Third, the findings suggest that ECM adoption is associated with frequent internal inspections. High-adopter plants conducted frequent environmental inspections and were subjected to regular inspections by corporate environmental staff. Internal inspections were far less common at plants in the low-adopter sample.

CONCLUSIONS

This paper has examined the role of organizational factors in the adoption of environmentally innovations. We advanced the hypothesis that organizational capabilities matter significantly in the adoption of ECM practices. We distinguished among three dimensions of organizational capabilities: organizational resources and capacity, organizational innovativeness, and organizational monitoring.

Our findings by and large confirm the main hypothesis. We found that organizational factors matter significantly in the process of ECM adoption, suggesting that too much explanatory weight has been given to external factors in previous research on this subject. We further found that while external factors do play a role, they provide only a limited explanation for why firms adopt environmental innovations. Organizational capabilities both encourage and act as obstacles to the process of ECM adoption. Furthermore, we found that two classes of organizational capabilities are particularly significant in the process of ECM adoption: organizational resources and organizational monitoring.

Organizational resources - particularly specialized environmental resources - appear to matter greatly in the process of ECM adoption. These resources provide the embedded capacity which enable firms to respond to external stimuli and implement environmental innovations. In effect, they create the opportunity space from which individual managers and work groups can experiment with and implement advanced environmental practices.

Organizational monitoring is also important. It provides a special type of organizational capability, which establishes quantitative objectives, goals, standards and evaluation metrics that enable sample organizations to assess their progress toward stated goals. The findings suggest that organizational monitoring is perhaps the key differentiating factor in ECM adoption.

In addition, our findings suggest that there is at best a loose association between organizational innovativeness, (measured as prior adoption of advanced business practices) and ECM adoption. We found a high rate of adoption of advanced business practices across high- and low-adopters in the sample. We believe this result reflects the widespread adoption of some version of advanced business practices by manufacturing establishments generally. We suggest however, that what distinguishes the ability of organizations to effectively utilize and theses practices are the adoption and use of organizational monitoring systems. Here, we contend that although advanced business practices may lead to improved business outcomes, they are alone insufficient to yield environmental performance gains.

Generally speaking, our findings suggest that organizational factors operate as a system. Organizational resources - particularly specialized environmental resources - create the capacity to respond to internal opportunities and external events. The use of quantitative goals and measurement systems provide the mechanism for focussing effort, identifying problem areas, and for measuring progress toward specified objectives. These systems enable organizations to optimize their processes in general, to improve their environmental process in particular, and to realize performance gains from adoption of innovative organizational practices broadly.

We encourage other studies to utilize this conceptual approach and to subject the concepts, claims and findings advanced here to rigorous empirical testing on larger samples of organizations.

APPENDIX

Appendix 1. Complete Organizational Factor Scores for Sample Plants

	HIGH ADOPTER								LOW ADOPTER				
FACILITY	A	B	D	F	H	I	K	AVG	C	E	G	J	AVG
ORGANIZATIONAL RESOURCES													
Facility Size	5	5	1	5	5	5	5	4.43	1	1	3	1	1.5**
Company Size	5	5	1	5	5	5	5	4.43	5	1	3	3	3
ORGANIZATIONAL RESOURCE SCORE	10	10	20	10	10	10	10	4.43	6	2	6	4	2.25*
ENVIRONMENTAL RESOURCES													
Size of Environmental Staff	3	4	3	5	5	5	4	4.14	2	1	2	1	1.5***
Experienced Environmental Staff	5	5	3	5	5	5	5	4.71	5	1	2	1	2.25***
Tenure of Environmental Staff	5	5	5	5	5	5	5	5	2	4	5	1	3*
ENVIRONMENTAL RESOURCE SCORE	13	14	11	15	15	15	14	4.62	9	6	9	3	2.25***
BUSINESS PRACTICES													
ISO Certified	0	0	0	5	5	0	0	1.43	5	5	5	5	5*
Mission Statements	5	5	0	5	5	5	5	4.29	5	4	3	0	3
Formal Quality Management System	5	5	0	5	4	2	4	3.57	5	0	0	0	1.25**
JIT Inventory Control	4	5	0	4	2	5	3	3.29	5	4	5	1	3.75
Cross-Functional Work Teams	2	3	0	5	5	2	1	2.57	5	4	4	0	3.25
Problem-Solving Teams	2	5	0	3	5	5	1	3.43	5	0	5	0	2.5
BUSINESS PRACTICE SCORE	21	23	0	22	21	19	14	3.10	25	12	17	1	3.13
ENVIRONMENTAL MONITORING & SYSTEMS													
Explicit Environmental Objectives	5	5	0	5	5	5	5	4.29	5	0	1	1	1.75**
Environmental Performance Monitoring	5	5	1	5	5	5	5	4.43	3	1	1	1	1.5**
Provide Environmental Information to Workers	5	5	0	5	4	5	2	3.71	1	1	1	2	1.25

Environmental Cost Identification	1	3	1	4	3	4	5	3	1	2	1	4	2
Chemical Control Process	1	5	0	0	4	4	2	2.29	4	0	0	0	1*
Regular Environmental Inspections	5	5	1	4	5	5	2	3.86	5	1	3	1	2.5
Environmental Audits of Suppliers	1	2	0	1	4	5	1	2	1	0	1	0	.05
MONITORING & SYSTEMS SCORE	23	30	3	24	30	33	22	3.37	20	5	8	9	1.5**
OVERALL SCORE	67	77	16	71	76	77	60	3.88	60	25	40	17	2.28**

Source: by authors

* significant at the .10 level, two-tailed test

** significant at the .05 level, two-tailed test

*** significant at the .01 level, two-tailed test

Atlas, Mark and Richard Florida. 1998. "Green Manufacturing", in Richard Dorf (editor), Handbook of Technology Management (CRC Press, 1998).

Atlas, Mark and Richard Florida. 1997. "Why Do Firms Adopt Green Design?: Organizational Opportunity, Organizational Resources, Costs, or Regulations" (unpublished working papers, Carnegie Mellon University, Heinz School).

Apaiwongse, Tom Suraphol. 1995. "Voluntary Reaction to Green Policies among Market-Mavens: An Application of the Parallel-Political Marketplace Conceptualization, in Environmental Marketing: Strategies, Practice, Theories, and Research" (M. Polonsky and A. Mintu-Wimsatt, Eds.), Haworth, Binghamton, NY.

Cohen, Wesley and Daniel Levinthal. 1990. "Absorptive Capacity: A New Perspective on Learning and Innovation", Administrative Science Quarterly 35, pp. 128-152.

Denton, D. Keith. 1994. Enviro-Management: How Smart Companies Turn Environmental Costs Into Profits (Englewood Cliffs, NJ: Prentice Hall).

Dillon, Patricia and Kurt Fischer. 1992. Environmental Management in Corporations: Methods and Motivation. Tufts University Press, Medford, MA

Florida, Richard. 1996. "Lean and Green: The Move to Environmentally Conscious Manufacturing", California Management Review, 39/1, pp. 80-105

Florida, Richard and Davis Jenkins. 1998. "The Japanese Transplants in North America: Production Organization, Location and R&D, in Steven Tolliday (editor), Between Imitation and_Innovation: The Transfer and Hybridization of Production Systems in the International Automobile Industry (Oxford University Press, 1998).

Georg, Susan, Inge. Ropke, and Ulrik Jorgensen. 1992. "Clean Technology Innovation and Environmental Regulation", Environmental. Resource Economics 2, pp. 533-550.

Gladwin, T. 1992. "Building the Sustainable Corporation: Creating Environmental Sustainability and Competitive Advantage", (Tufts University Press, Medford, MA).

Green, Kenneth, Andrew McMeekin, and Alan Irwin. 1994. "Technological Trajectories and R&D for Environmental Innovation in UK Firms", Futures 26, pp. 1047-1059.

Groenewegen, P. and P. Vergragt. 1991. "Environmental Issues as Threats and Opportunities for Technological Innovation", Technol. Anal. Strategic Management, 3, pp. 43-55.

Hart, Stuart and Gautum Ahujba. 1994. "Does it Pay to be Green? An Empirical Examination of the Relationship between Pollution Prevention and Firm Performance", unpublished paper, University of Michigan, School of Business Administration, Corporate Environmental Management Program.

Ichniowski, Casey, Kathryn Shaw and Giovanna Prennushi. 1993. "The Effects of Human Resource Management Practices on Productivity", Columbia University, Carnegie Mellon University and the World Bank. Draft Manuscript.

Jenkins, Davis and Richard Florida. 1998. "Work System Innovation among Japanese Transplants in the United States," in Paul Adler, Mark Fruin and Jeffery Liker (editors), Remade in America: Japanese Transplants and the Diffusion of Japanese Production Systems (New York: Oxford University Press, forthcoming).

Kemp, R, and X. Olsthoorn, F. Oosterhuis, and H. Verbruggen. 1992. "Supply and Demand Factors of Cleaner Technologies: Some Empirical Evidence", Environmental Resource Economics, 2, pp. 614-634.

King, Gary, Robert O. Keohane, and Sidney Verba. 1994. Designing Social Inquiry: Scientific Inference in Qualitative Research. Princeton University Press.

Lawrence, A. and D. Morell. 1995. "Leading-Edge Environmental Management: Motivation, Opportunity, Resources, and Processes," in Research in Corporate Social Performance and Policy: Sustaining the Natural Environment þ Empirical Studies on the Interface Between Nature and Organizations, Supplement 1. (J. Post, D. Collins, and M. Starik, Eds.), JAI, Greenwich, CT.

MacDuffie, John Paul. 1994. "Human Resource Bundles and Manufacturing Performance: Flexible

Production Systems in the World Auto Industry". Wharton School, University of Pennsylvania.

Makower, Joel. 1993. The e-Factor: The Bottom-Line Approach to Environmentally Responsible Business (New York, NY: Times Books).

Maxwell, James, Sandra. Rothenberg, and B. Schenck. 1993. "Does Lean Mean Green: The Implications of Lean Production for Environmental Management", Prepared for International Motor Vehicle Program, MIT.

North, Klaus. 1992. Environmental Business Management: An Introduction (Geneva: International Labour Office).

Office of Technology Assessment. 1992. Green Products by Design: Choices for a Cleaner Environment (Washington, D.C.:U.S. Government Printing Office).

Office of Technology Assessment. 1994. Industry, Technology, and the Environment: Competitive Challenges and Business Opportunities (Washington, D.C.: U.S. Government Printing Office).

Osterman, Paul. 1994. "How Common Is Workplace Transformation and Who Adopts It?", Industrial and Labor Relations Review, 47/2.

Porter, Michael E. 1991. "America's Green Strategy", Scientific American.

Porter, Michael and Claas van der Linde. 1995a. "Green and Competitive: Ending the Stalemate", Harvard Business Review, pp. 120-134

Porter, Michael and Claas van der Linde. 1995b. "Toward a New Conception of the Environment-Competitiveness Relationship", Journal of Economic Perspectives, 9/1, pp. 97-118

Post, J. and B. Altman. 1992. "Models or Corporate Greening: How Corporate Social Policy and Organizational Learning Inform Leading-Edge Environmental Management", in Research in Corporate Social Performance and Policy: Markets, Politics, and Social Performance, (J. Post, Ed.), JAI, Greenwich, CT.

Schmidheiny, Stephen. 1992. Changing Course: A Global Business Perspective on Development and the Environment (Cambridge, MA: The MIT Press).

Schot, Johan. 1992. "Credibility and Markets as Greening Forces for the Chemical Industry," Business Strategy Environment 1, pp. 35-44.

Smart, Bruce (ed.). 1992. Beyond Compliance: A New Industry View of the Environment (Washington, D.C.: World Resources Institutes).

Teece, David and Gary Pisano. 1994. "The Dynamic Capabilities of Firms: An Introduction", Industrial Corporate Change, 3, pp. 537-556.

Winn, M. 1995. "Corporate Leadership and Policies for the Natural Environment", in Research in Corporate Social Performance and Policy: Sustaining the Natural Environment Empirical Studies on the Interface Between Nature and Organizations, Supplement 1 (J. Post, D. Collins, and M. Starik, Eds.), JAI, Greenwich, CT.

Winn, S.F. and NJ Roome. 1993. "R&D Management Responses to the Environment: Current Theory and Implications to Practice and Research", R&D Management 23, pp. 147-160.

Winter, Sidney. 1987. "Knowledge and Competence as Strategic Assets," in The Competitive Challenge: Strategies for Industrial Innovation and Renewal, (David Teece, Ed.), Harper Row, New York.

Womack, James, Daniel Jones and Daniel Roos. 1990. The Machine that Changed the World. (New York, NY: Rawson and Associates).

C. The Cost of Environmental Regulation

Presentation by William Pizer

[Full paper by Richard D. Morgenstern, William Pizer and Jhih-Shyang Shih available at http://www.rff.org/disc_papers/PDF_files/9836.pdf]

The Cost of Environmental Regulation

Richard D. Morgenstern
William Pizer
Jhih-Shyang Shih

ELI/CMU Conference
on Cost, Innovation and
Environmental Regulation
April 30, 1999

RESOURCES
FOR THE FUTURE

Motivation

- Expenditures on environmental regulation are estimated at 2% of GDP or $150 billion *based largely on self-reported information.*

- Could self-reported estimates fail to capture the real resource cost of environmental regulation?

Why might reported costs be "wrong"?

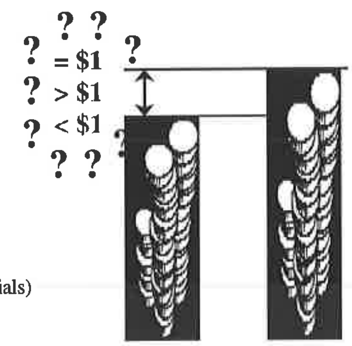
- Crowding out of other investment.
- Regulations are biased against new sources.
- Loss of operating flexibility
- Complementarities between regulatory and productive activities.
- Porter hypothesis.

- On balance, empirical literature suggests *understatement.*

Strategy

	1980	1981
Reported Environmental Expenditures	$100	$101

Total Production Costs (capital, labor, energy, materials)



Census Data

- Data on 142 pulp & paper plants, 107 plastics plants, 165 petroleum plants, 127 steel plants.
- Combine data over six years from three data sets: Longitudinal Research Database (LRD), Manufacturing Energy Consumption Survey (MECS), Pollution Abatement and Control Expenditure (PACE) survey.

Estimation Results

A

<u>$1 increase in reported environmental expenditures</u>

is associated with the following

<u>increase in total costs</u>:

$0.64 ± 0.52	pulp and paper
$0.20 ± 1.12	plastics
$0.78 ± 1.52	petroleum
$1.41 ± 0.84	steel
$0.82 ± 0.84	all four sectors

Conclusions

- No strong evidence of under- or over-statement of reported environmental costs.
- Slight over-statement possible in pulp and paper, plastics, and petroleum. Slight under-statement possible in steel.
- Best estimate: $0.82 ± $0.84 increase in total costs for a one dollar increase in reported environmental expenditures.
- Contradicts results other authors that often finds dramatic under-statement.

D. On the Accuracy of Regulatory Costs

Presentation by Winston Harrington

[Full paper by Winston Harrington, Richard Morgenstern and Peter Nelson available at http://www.rff.org/disc_papers/PDF_files/9918.pdf]

The question of whether the costs of government health and environmental regulation are over- or underestimated is very contentious, but a close look at the controversy suggests that the protagonists are really talking about two different questions. On the one hand, those who believe costs are underestimated often have in mind the costs of an entire program or legislative initiative, asserting that all too frequently the scope and cost of those programs spin out of control. In addition, it is said that the most important costs of such regulation are never even counted, including regulation-induced job losses, claims on management attention, discouraged investment, and retarded innovation. In contrast, those who believe costs are overestimated prefer to look at the direct costs of complying with specific regulations.

It would of course be most useful to put to empirical test both these assertions, but unfortunately the first one is essentially untestable. Accordingly, in this paper we examine only the second one. We compare *ex ante* estimates, made at the time the regulation is being considered, of the direct costs of individual regulations to *ex post* assessments of the same regulations. For *total* costs our results support what we take to be the conventional wisdom, namely that the costs of regulations tend to be overestimated. We find this to be true for 12 of the 24 rules in our data set, while for only two rules were the *ex ante* estimates too low. For *unit* costs, however, the story is quite different. At least for EPA and OSHA rules, unit cost estimates are often accurate, and even when they are not, overestimation of abatement costs occurs about as often as underestimation. In contrast, for those rules that use economic incentives, unit costs are consistently overestimated. The difference between the total-cost and the unit-cost results is due to the frequent errors in estimates of the effects of individual rules, which suggests, in turn, that the rule's benefits may also be overestimated. The quantity errors are driven both by difficulties in determining the baseline and by incomplete compliance. Technological innovation appears to be an important cause of unit cost overestimation, especially for economic incentive rules.

Background

- *Ex ante* cost estimate -- *Forecas*t of the cost of a regulation prior to implementation (in RIAs)

- *Ex post* cost estimate -- *Measurement* of a regulation's cost after implementation

Background (cont.)

- Different perspectives on the issue
  - Business: EPA *underestimates* the cost of *programs*
  - Environmentalists: EPA *overestimates* the cost of *regulations*
- Different definitions of the problem
  - Is the problem that important cost categories are left out of (or improperly included in) the estimates?
  - Or that costs are poorly estimated?

What we did

- Surveyed 24 case studies
- Examined 3 outcomes
  - Total cost
  - Unit cost
  - Quantity reduction

Terms:

- Accuracy - ± 25 percent
- Regulatory
  - EPA, OSHA, California, International
  - Individual regulations: no legislation, no programs
- Cost -
  - Direct compliance cost only
  - No indirect cost, GE effects, etc.
- Estimates - By government agencies only

Results - all cases

	OK	Over	Under
TC	5	12	2
UC	7	12	5
Quant	9	9	4

Results - Federal rules

	OK	Over	Under
TC	4	10	2
UC	6	6	5
Quant	7	9	1

Results - EPA

	OK	Over	Under
TC	3	4	1
UC	3	3	3
Quant	4	4	1

Results - EI

	OK	Over	Under
TC	2	4	0
UC	1	7	0
Quant	3	1	4

Reasons for errors

- Technical Change
- Calculation of baseline
- Changes in rules

Conclusions

- Total costs are usually overestimated
- Effectiveness of regulation is overestimated also
- Unit cost estimates are more accurate
  - Especially for federal rules
- Unit costs are most frequently overestimated for EI policies

Part III

Panel 2: Research on Incentives and Barriers to Innovation

Moderator: Byron Swift, Director, Energy and Innovation Center, Environmental Law Institute

A. Does Environmental Regulation Discourage Technological Innovation?

Presentation by Kurt A. Strasser, Associate Dean and Professor, University of Connecticut School of Law

Environmental regulation certainly can discourage technology innovation. Consider Monsanto v. EPA[2], a troubling example. EPA's new regulations required removal of 95% of the benzene from emissions of a number of sources, including Monsanto's monochlorobenzene manufacturing plant. The established and familiar technology for doing this, carbon adsorption, had an unattractive side effect: it generated a hazardous waste requiring treatment and storage. Monsanto chose to try an alternative technology, water scrubbing, because it allowed recovery and reuse of the benzene and did not generate the hazardous waste. The choice made sense; tests of water scrubbing achieved 99% reduction. However, when the system was installed, it achieved only 80% reduction and Monsanto had to install a supplementary adsorption system to get up to 95%. In this case, EPA sought to impose penalties for the additional time it took Monsanto to install the supplemental adsorption system, reasoning that if Monsanto had simply used the familiar adsorption technology, the job would have been completed by then.[3] The EPA's penalty

[2] 19 F.3d 1201 (7th Cir, 1994).

[3] The EPA had initially granted an eleven month waiver to allow installation of the water

effort in this case would surely discourage future efforts to try new technologies, even those that offer potential environmental benefits. The sad part is that the EPA's thinking here is far from aberrant and is, indeed, consistent with regulatory values that emphasize pollution control, with familiar technology.

This story does have a somewhat happier ending. Monsanto sued, and the Seventh Circuit Court of Appeals ultimately held that the agency's action was arbitrary and capricious and could not be sustained. The court lectured the EPA to avoid the short-sighted and bad environmental policy[4] of insisting on a quick fix regardless of its net adverse environmental impact. This lecture offers worthy advice, but it is discouraging that the Court of Appeals had to lecture the EPA on environmental policy.

Monsanto illustrates how environmental regulation can discourage application of new technology. This is not surprising in view of the job the regulatory system was originally given. The system's original core mission is to protect public health and the ecosystem by forbidding and stopping harmful contact. Getting basic rules in place and getting them enforced is crucial, and regulators often develop a law enforcement mentality with little trust of regulated companies. However, this system is awkward, and sometimes counterproductive, in trying to spur the development and application of new technology that must, for the most part, come from business creativity and research rather than government fiat.

Yet Monsanto and its discouraging message is not the whole story. There is a substantial

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scrubbing system, but denied a further waiver to install the supplemental adsorption system.

[4] See Monsanto, 19 F.3d at 1206. The court also held that the facts did not support EPA's conclusion that the adsorption system could have been installed in time.

body of case study evidence, much of it in the work of Professor Nicholas Ashford, that environmental regulation sometimes provokes innovation and diffusion of new technology.[5] When PCB's were banned, industry reaction were diverse, but some ultimately produced the needed innovation.[6] Monsanto, the only US manufacturer, voluntarily restricted sales and then exited the market. In contrast, Dow Corning and GE developed substitutes and then used them to enter the market. New limits on sulfur dioxide emissions by the copper industry lead to similar responses.[7] The dominant firms first challenged the rules in court, and then installed available pollution control technology. However, copper mining firms went much further, developing a new, cleaner smelting process and using it to enter the business. While case studies can not show that regulation always, or even typically, supports innovation, they do show that it can. Policy tools must be used creatively, and matched to the industry and firm situations conducive to innovation, to do so.

While the regulatory system was conceived and implemented as a system of controls, specifically controls on polluting behavior of industry, we should also think of it as a set of incentives. The regulatory system is a most potent motivator of businesses, but it's record of

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[5] See, e.g., Ashford, An Innovation Based Strategy for the Environment, in Worst Things First (Finkel & Golding eds, 1994) at 275; Ashford, Ayers and Stone, Using Regulation to Change the Market for Innovation, 9 Harv. Envtl. L. Rev. 419 (1985; Ashford & Heaton, Regulation and Technological Innovation in the Chemical Industry, 46 L. & Contemp. Probs. 109 (1983).

[6] Ashford, Ayers and Stone, supra n. 4, at 432-33.

[7] See Strasser, Cleaner Technology, Pollution Prevention and Environmental Regulation, IX Fordham Envtl. L. J. 1, at 28-32 (1997) for a review of this and other case studies.

motivating the development of environmentally better technology is mixed and uncertain at best.[8] While controls are intended as straightforward incentives to prohibit bad behavior, the controls we use now often do not work to either require or inspire creation and use of new, more environmentally friendly technology.

I. Environmental regulation's preference for familiar technology.

Familiar technology supplies the reassurance of adequate performance, certainty of results, and low risk to participants that environmental regulation, and indeed all regulation, values. This shows through most clearly in the permitting process.[9] Permit writers must decide if an applicant's proposed technology will comply with regulatory standards, and familiar technology is easiest to evaluate. Further, permit writers who stay with familiar technology do not run the risk of writing problem permits that may have adverse career consequences. Because permits are easier to get with known technology, the industry counterpart to the permit writer is most likely to propose it; after all, she has just a great a professional and personal need for reliable performance, with no surprises and violations. Recent survey evidence confirms that technology vendors and users see the permitting process as a major impediment to use of new technology.[10]

In addition, familiar technology is prominently featured in the rulemaking process.[11] For

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[8]By "the regulatory system" I mean the traditional process of writing rules, issuing permits, and enforcement. Current voluntary programs are beyond the scope of this paper; for a summary, see EPA, Reinventing Environmental Protection (March 1999) pp. 33-35.

[9]For a survey of the literature, see Strasser, supra n. 6, at 67-72 (1997).

[10]EPA, Stakeholder Attitudes on the Barriers to Innovative Environmental Technology, (EPA 236-R-98-001, June, 1998) pp. 12-18.

[11]See Strasser, supra n. 6, at 20-44.

the most part, our specific environmental rules set undemanding standards based on existing technologies. As a result, there is no regulatory reward for exceeding these standards, and thus little incentive to develop the technologies that could do so.[12] Further, the formality and delay of regulatory rulemaking mean that it will always be discussing somewhat dated existing technology, and the likelihood of judicial review forces regulators to stay with technological choices that can be credibly explained to a non-expert federal court of appeals. Once a standard has been set, it is difficult to change to reflect new technology or for other reasons. Finally, the system demands medium specific rules, so the tendency is to comply using gadgets that go on the end of the pipe or smokestack. This is unfortunate, for more comprehensive rules might lead to more technology innovation back inside the plant where there is greater potential for overall environmental (and other) gains.

The enforcement process also emphasizes known, familiar technology.[13] With enforcement, a potential law violation is at stake and both regulators and companies have a greater need for certainty and less appetite for the risks of innovation. Further, there is little time left for real new development when enforcement looms, so the chance of developing true innovations is not great.

When environmental regulation is seen as a system of public controls, the preference for familiar technology is understandable. An unfortunate consequence, however, is that technological possibilities are constrained and the opportunity to support the development of new

[12]Stakeholder Attitudes, supra n. 9, at 14 reports that regulators and vendors see this as a major problem.

[13]For a survey of the literature, see Strasser, supra n. 6, at 84-88.

technology is missed.

II. The risks of new technology.

New technology is risky for regulators and for their counterparts in business, and these risks may well discourage them from pursuing its environmental potential. Technological innovation is an uncertain and time consuming process. New technology may not work perfectly, particularly at first, and it may not work on time. This presents risks for the all parties on the front end, as well as potential compliance and enforcement problems on the back end. Three kinds of problems are central.

First, regulators have a difficult time evaluating new technology, whether they are writing regulations, issuing permits, or enforcing them. Regulators tend to know the most about the existing technology which is typically an end of the pipe or smokestack application. More innovative technology at the end of the pipe may well be unfamiliar, but the most innovative efforts are likely to involve production processes and materials inside the plant, and regulators will know these least well. Thus, regulators worry that the new technology will not protect the public, and approval of it will present career risks within the agency. Recent survey evidence shows that regulators see the lack of adequate performance data as one of the greatest barriers to use of innovative technology.[14] This perception confirms that regulators, and the regulatory system, will have trouble evaluating innovative technology, and thus be less likely to embrace or support it.

[14]Stakeholder Attitudes, supra n. 9, at 24.

In addition, truly innovative technology may change the waste stream in ways that, while offering a net environmental benefit, may bring the company greater regulatory scrutiny. If, for example, a company redesigns its manufacturing process or the product in ways that greatly decrease air emissions but somewhat increase water discharges, new water permits will be needed and new air permits may be. If the manufacturer begins recycling or reusing what was previously a hazardous waste stream, it may become a RCRA TSD (treatment, storage, disposal) facility. In this unhappy circumstance, the manufacturer has to get permits under, and then operate subject to, what is probably our most demanding regulatory program. This will often not be worth the trouble, particularly for a company not primarily in the waste disposal business, and the environmental benefits of the recycling and reuse will be lost.

Finally, new technology will sometimes fail, and these failures presents difficult policy problems. While discussions of innovation tend to emphasize success stories, not all efforts at innovation are successful and regulators must decide what to do with the failures. Monsanto, discussed above, shows a hard line enforcement policy, and this must surely discourage innovation. A technology friendly environmental policy must include a fail-soft component that protects against the worst of the consequences of failure for a good try.[15] Some protection is needed for delayed compliance, both when the technology eventually works and when it fails completely and must be replaced by an alternative. Further, the promise of such protection is needed in advance, as policy, to encourage developing the technology.

At the present time, the risks presented by innovative environmental technology

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[15]For a further discussion, see Strasser, supra n. 6, at 65-66.

discourage both its development and its use. Environmental technology is frequently seen as a bad investment because slow regulatory approval of it delays any return on the investment, and because the risk that it may not be approved (and may not work) make any return on the investment speculative. The well documented dearth of venture capital funding for environmental technology shows clearly the impact of these risks.[16]

III. Policy responses to support innovation.

The problems recounted here are not new, and there is a substantial history of agency efforts to respond; a few programs will be surveyed here. Unfortunately, this history does not inspire confidence. It is a history of pilot programs, bold initiatives, and other one-shot efforts. Some have seen modest success, other have not. However, none have grown and become institutionalized within the regulatory system, and thus none have seriously addressed that system's problems with new technology discussed above.

Both the Clean Air Act and the Clean Water Act authorize waivers of regulatory requirements and special permitting to promote innovation, and this is potentially an attractive strategy. However, these programs have generally not been successful.[17] They present too many risks for all the parties involved, and regulators think they are too resource intensive for the environmental protection payoff. Technology certification programs are currently being pursued

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[16]Stakeholder Attitudes, supra n. 9, at 3-5.

[17]Strasser, supra n. 6, at 60-64.

at both the state and federal levels, and, if successful, these would ease the special burden regulators have in approving new technology.[18] However, certification must overcome substantial internal agency risks posed by new technology, so expectations must be realistic.

Other regulatory payoffs for innovative pollution prevention efforts, such as easier or faster permitting, have been proposed and the EPA has introduced substantial flexibility in the way it provides funds to states in order to support such programs.[19] The efforts offer real potential, particularly because they are more widespread than the typical pilot program, but they are too new to evaluate.

To encourage better environmental performance, some alternative permitting programs are being tried. In essence, these offer individually negotiated environmental standards or practices in exchange for improved environmental performance by the company. Project XL is the best known. Its announced goal in 1995 was 50 pilot projects; 10 have been approved to date and 20 others are reported to be in negotiation.[20] Such individually negotiated deals are hard, particularly given the public arena in which negotiations must take place and EPA's limited statutory authority to negotiate diverse standards under many environmental statutes. This may prove a useful learning experience as a pilot program, but the time demands of individual negotiations will effectively preclude this from becoming a meaningful substitute for most of the regulatory system. There is to date no comprehensive evaluation of the extent of new technology

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[18]Stakeholder Attitudes, supra n. 9, at 3.

[19]Reinventing Environmental Protection, supra n. 7, at 26-30.

[20] Reinventing Environmental Protection, supra n. 7, at 48-50.

promotion in the approved projects.

IV. Changing the regulatory system to promote environmental technology.

A robust environmental technology policy will be difficult to fit into the present regulatory system. Such a policy must begin with an understanding of the how and why technology innovation takes place. Yet the development of new technology is not a complete unknown. There is a substantial body of knowledge that can be brought to bear on the question of why and how new technology gets developed.[21] To be effective, environmental technology policy can use this body of knowledge to target rulemaking, permitting and enforcement to spur technology development. This will require careful consideration of the industry and firm characteristics that are typically associated with technological change, as well as a realistic assessment of the technological options and possibilities in a specific industry. For example, is the firm's core technology rigid and mature, or is it still developing and flexible? Are product changes, typically from fringe firms and outsiders, or process changes, typically from established insiders, more likely? If the firms in the industry are not likely to be moved by regulatory policy, are there other likely innovators upstream, downstream or elsewhere?

Such an effort must consider the instances in which regulatory policy has provoked change. As discussed above, there is good case study evidence that strict pollution limits and product bans have sometimes provoked technological innovation.[22] With many of these, the

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[21]For an introduction, see Strasser, supra n. 6, at 8-20.

[22]See the discussion accompanying footnotes 4-7 above and the sources cited there.

kinds of technological innovation that individual firms undertook, or did not undertake, was reasonably predictable from the industry setting and the firm's position in it. For example, we would expect dominant firms operating with a mature technology to be only modestly innovative, at best, and this is what happened when copper smelters simply used off-the-shelf pollution control devices in response to new sulfur dioxide regulation. In contrast, we would expect more innovative responses from outsiders wishing to get into the smelter business, and this is what happened when copper mining firms reacted to the new regulations by developing new smelter processes and using them to enter the industry. The literature referred to above discusses a number of specific cases in which regulation has provoked technological innovation, often predictably. With a clearer appreciation of the possibilities for technological innovation in a particular industry, regulators could target their efforts enforcement much more effectively.

To do this, regulators could use the authority they have under present statutes to ban products or strictly regulate emissions, when either is likely to be motivate innovation. This authority exists under many statutes, although it has not been much used.[23] For example, the Clean Water Act authorizes product bans for discharges of toxics, and it appears to authorize setting effluent standards with reference to pollution prevention technologies. Similarly, RCRA's requirements of pollution prevention, and its land-ban provisions, could be used to provoke innovative technological responses.[24] Regulators could use this authority to target rules for innovation effects, if they had an accurate assessment of the potential for technological innovation

[23]Strasser, supra n. 6, at 55-60; ELI, The Tools of Prevention: Opportunities for Promoting Pollution Prevention under Federal Legislation (1993).

[24] Id. at 58-59.

in an industry.

However, a robust use of regulation to provoke technological innovation would ultimately require a fundamental change in our current medium-specific regulatory structure. We now regulate air, water, and land disposal of wastes separately. Yet the business decisions that generate pollution and wastes are not medium specific decisions; they are decisions about products, production technologies, and materials that are multi-media decisions in that they have multi-media impacts. Comprehensive, multi-media regulation is needed to have the maximum impact on those decisions, and ultimately on the resulting pollution and wastes. Further, a multimedia approach will require that regulatory agencies be structured around industry groups, rather than environmental media, so they will develop expertise in the technological possibilities of those groups. Such a regulatory system can send to industry a multi-media message, one well informed by knowledge of the industry's innovation potential, and this can require or inspire real innovation.[25] There have been some EPA pilot project efforts to use a multi-media approach to rulemaking under the current system, including the Source Reduction Review Project, but these have not been particularly successful. In enforcement, negotiated Supplemental Environmental Projects can be used to adopt specific multi-media innovations.[26] A number of state initiatives in permitting and enforcement are underway, and the EPA is supporting these with a new system of giving grants to states that emphasizes regulatory flexibility.[27] All of these efforts are

[25] There is a large literature on the benefits of comprehensive multi-media regulation. See Strasser, supra n. 6, at 45-51.

[26] Id. at 94-99.

[27] Reinventing Environmental Regulation, supra n. 7, at 26-30.

commendable, although no comprehensive evaluation is possible yet, and all are still pilot projects and other demonstration efforts rather than fully institutionalized reforms. The history of such efforts gives pause, and it appears that fundamental restructuring of the regulatory statutes and the agencies operating under them will be required.

In sum, environmental regulation can discourage innovation, and doubtless frequently does so. However, this has not uniformly been the case. Technological innovation is a somewhat predictable process, one that a sophisticated regulatory system could target for optimal effect. The regulatory history so far is of piecemeal efforts, pilot programs and other one-shot attempts that have never become institutionalized within the regulatory agencies. While these incremental efforts offer some potential gains if pursued on a broader scale, a robust environmental technology policy will require fundamental reform of the whole system.

B. Remarks On Environmental Regulation, Firm Behavior and Innovation

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"The future is not what it used to be."
[Paul Valéry]

1. Introduction

Environmental regulation has a relatively long history. In his provocative book on technological innovation in the Middle Ages, for instance, Gimpel (1975) tells of a Royal decree of 1307 forbidding the use of sea coal in the London area. This type of coal was extracted just below the surface of some seashore areas in Durham and Northumberland counties and was abundant in those days. Its energetic performance was rather poor by modern standards; its smoke smelled badly and entailed significant health hazards. However, substitutes to sea coal, namely charcoal or higher-quality coal coming from Scotland, were rather expensive. A special enforcement agency had therefore to be created, in order "to find out all individuals burning sea coal in the city or its surroundings, to impose large fines on them right away, and to destroy their ovens in case of repeated offense." In another story, on September 7th, 1366, the French Parliament ruled that slaughter houses and tanneries be located on the Seine river downstream of Paris. Brewers were amongst the most vocal supporters of this decree, for slaughter houses and tanneries strongly degraded water, their main input. Each year then, about 250,000 animals were killed in Paris; tanning and butchering accounted for hundreds of tons of hazardous organic waste being thrown in the river. The new rule was thus well received by the population in general, although it affected negatively the production of slaughter houses and tanneries (that were crucial to virtually all urban economies in those days) by sensibly raising their transportation costs.

These examples illustrate two major points that remain largely uncontroversial amongst economists and environmental policy makers. First, the purpose of environmental regulation is to correct for negative externalities that decrease social welfare. Secondly, environmental regulation would usually impose costs on someone (usually the polluter).

The last decade, however, has seen these assertions face a mounting challenge. The initial proponents of an alternative view of environmental regulation came from the applied field of business policy. Their perspective has been most clearly and forcefully summarized in the work of Professor Michael Porter and is now known as the Porter hypothesis [Porter (1996), Porter and van der Lind (1995)]. According to it, environmental regulation can (and should) also be seen as an industrial policy instrument aimed at increasing the competitiveness of firms, the underlying justification for this statement being that well-designed environmental regulation could force firms to seek innovations that would turn out to be both privately and socially profitable. Such an assertion is of course quite appealing to policy makers, for it suggests that environmental regulation could be win-win, i.e. that *all* parties could possibly benefit from it, *including* those responsible for creating negative externalities.

There are many examples that currently support the Porter hypothesis. The success of 3M's Pollution Prevention Pays program, for instance, has been widely publicized: between 1975 and 1992 this program triggered 3,000 pollution-preventing projects that lead to savings of the order of $530 million.28 Less well-known but equally suggestive are the cases of Eka-chimie and Ciment St-Laurent, two Québec-based firms [Lanoie and Tanguay (1998)]. The former, a 75-employee firm, produces sodium chlorate. In recent years it amended significantly its production process in order to reduce water and energy consumption and decrease expenses on the mandatory treatment of effluents. Those changes costed $900 thousand but lead to immediate savings of $600 thousand in the treatment of effluents, of $2 million a year in energy consumption and of $500 thousand per year in production itself. The latter is a concrete factory that employs 200 people. It recently substituted used tires for coal in its ovens. Total cost of this action is evaluated at $600 thousand a year, but savings from the purchase of tires instead of coal amount to $1.1 million per year.29

Despite the abundance of such cases that confer it some plausibility, however, the Porter hypothesis still lacks theoretical foundations that would clarify its scope and convince the critics. The main objection that needs to be met is summarized in the economist's well-known maxim: "There is no free lunches." Accordingly, innovation itself is not free, and if one prices managerial time and all other inputs correctly at their opportunity cost, it should become clear that putting stronger environmental requirements on polluting firms generally increases their production cost more than their revenue [see, for example, Palmer, Oates and Portney

28 ELI (1999) presents other examples and a summary of some empirical studies relating to the Porter hypothesis.

29 To conclude rigorously that these innovations truly brought positive net social benefits, however, some general equilibrium analysis would be necessary.

(1995)]. There can be notable exceptions, of course: stricter environmental regulation obviously benefits environmental consultants and lawyers, as well as developers of green technologies; it might also make a few polluting firms better off *ex post*, either by luck or by making them be the first ones to move ahead on adopting some new process, technology or product. But success stories and win-win situations are certainly not the rule.

At this point, it seems that no compelling theory in favor of the Porter hypothesis will come from avoiding altogether the paradigm and discourse of neoclassical economics. A more fruitful program rather consists in opening up some of the field's well-known "black boxes", following and refining the advances of mainstream economics on relevant topics such as innovation [Rosenberg (1982)] or the management of the firm [Milgrom and Roberts (1992); Gibbons (1998); Tirole (1999)]. In our initial joint work on environmental economics, Landis Gabel and I have repeatedly emphasized this approach [Gabel and Sinclair-Desgagné (1993; 1994; 1995)]. This paper presents and extends the results obtained so far that seem most useful for a better understanding of the Porter hypothesis and the consequent improvement of environmental regulation.

This presentation unfolds as follows. The next section focuses on current justifications for the existence and pervasiveness of low-hanging fruits, i.e. of cheap incremental innovations that firms just see after facing some pressure. Section 3 deals with innovations that specifically reduce the risk of a major environmental accident; those innovations deserve special attention because they relate to *nondeterministic* environmental externalities whose elimination might therefore be hard to value. Section 4 is devoted to radical innovations, which I believe to be the ones the Porter hypothesis mainly refers to. Section 5 contains concluding remarks concerning environmental regulation.

2. Low-hanging fruits

There seems to be anecdotal evidence that low-hanging fruits are abundant. In addition to the 3M case of the introduction, another illustration of this is provided, for instance, by the eighteen-month project run by the Centre for the Exploitation of Science and Technology in the United Kingdom, in order to enhance waste reduction and the use of cleaner technologies: in total the 11 participating companies saved more than £11 million a year, mostly from simple changes in processes which reduced inputs of water, energy and raw materials.

Standard neoclassical-economics models, however, do not support the systematic presence of low-hanging fruits. The reason is that, in these models, firms are perfect and never fail to implement a profit maximizing strategy. Few environmental economists have so far attempted to relax this assumption. *Yet it seems inconsistent to keep assuming that markets are imperfect while firms are not.* Furthermore, the modern economic theory of the firm now offers helpful ideas for capturing organizational failures in a rigorous, non-adhoc way.

Once it is accepted that firms do not act as single-minded omniscient entities, it is not hard to cope with low-hanging fruits. Multi-person units may fail for a variety of reasons which relate to either *incentive* or *coordination problems*. Failures of the former type have so far received the most attention and are now well understood. In their seminal paper on the multitask principal-agent problem, for instance, Holmström and Milgrom (1991) show that ill-designed compensation packages and difficulties in performance assessment can draw a manager's attention away from certain tasks. This provides a rationale for one natural explanation of low-hanging fruits, which invokes sudden shifts in employees' attention towards environmentally-friendly activities. Models like the one studied in Sinclair-Desgagné (1994) also capture some features of centralization that can lead a firm to momentarily overlook some good business opportunities.

Several interesting principles for the design of environmental regulation emerge from these analyses. Most importantly, environmental regulators should add to their traditional set of instruments - pigouvian taxes, quotas, tradeable pollution permits, command-and-control systems - tools that pierce the corporate veil, such as corporate liability or mandatory standards for environmental management systems. This might not only decrease the cost of enforcement of and compliance with environmental regulation, it is also possible that the instruments deployed by the regulator enhance the firm's own internal incentive system.30 In the latter case, we would have a win-win situation.

Low-hanging fruits can also arise from ex ante coordination failures within the firm. Coordination is generally achieved through communication and habits. Several models now capture communication problems that result in systematic errors and losses [see Sah and Stiglitz (1986);

30 The latter is an original idea that could be inferred from Segerson and Tietenberg's (1992) work, for instance. It needs to be examined further.

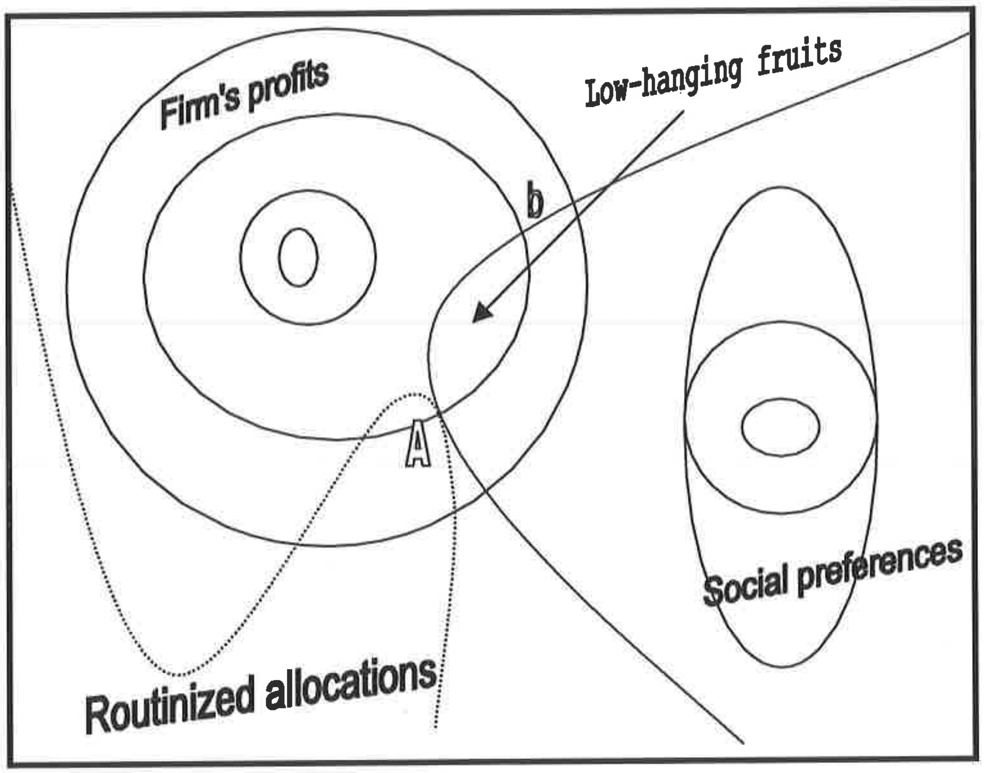
Radner (1992); Bolton and Dewatripont (1994)]. These models suggest that regulatory requirements on information production can have a significant impact on a firm's operations, leading to a profitable harvest of low-hanging fruits.31 The other type of coordination failure, that due to habits which keep a firm away from the global optimum, has recently been explored by Gabel and Sinclair-Desgagné (1998; 1999).

The fact that firms' decisions are constrained by production habits is well-documented. According to Cyert and March (1992), for instance, "The way in which the organization searches for alternatives is substantially a function of the operating rule it has. (...) The organization uses standard business procedures and rules of thumb to make and implement choices. In the short run these procedures dominate the decisions made." By forcing a firm to reconsider its actual processes and reengineer its existing routines, stricter environmental regulation might actually bring the firm closer to its own private optimum. This situation is illustrated in figure 1.

This figure depicts the level curves of two hills corresponding respectively to the firm's profits and to social preferences over the firm's production. The fact that the summits do not coincide means that there is some externality generated by the firm. Assume that the firm initially optimizes but over the one-dimensional locus indicated by the dotted curve. This locus represents a routine, in the sense that picking a point on it determines *without further deliberation* how much of the elementary inputs shall be used. The regulator, who does not presumably have better knowledge nor optimization capabilities than the firm, would seek to implement point A. One can see that, if the firm thereby revises its current routine, then there is a win-win region inside the two arcs starting at point A and meeting at *b* where both the firm and society could be made strictly better off. This captures the argument that low-hanging fruits are often found when environmental regulation pushes the firm to revise carefully its current processes and methods.

31 This again needs to be checked more carefully.

Figure 1. Routine-induced low-hanging fruits



Most economists will probably remain unsympathetic to this type of illustration, because it seems to rely on firms being systematically ignorant of production opportunities and improvements. The illustration, however, does not depart from the standard framework of optimization; it simply takes seriously the fact that the elements of a firm's choice set, or its inputs, *always* sit on more basic, elementary, often unconscious ones. One rationale for this was formulated some time ago by Alfred North Whitehead and runs as follows:

> "it is a profoundly erroneous truism, repeated by all copy-books and by eminent people making speeches, that we should cultivate the habit of thinking of what we are doing. The precise opposite is the case. Civilization advances by extending the number of operations which we can perform without thinking about them."

This rationale was recently formalized within a standard optimization framework [see Sinclair-Desgagné and Soubeyran (1999)].

An important implication of the latter line of arguments is finally that reengineering, defined as tracing down elementary inputs and bunching them back into better routines, always delivers low-hanging fruits. However, reengineering can also be quite costly, so that the firm might not (ex ante or ex post) find it worth undertaking. Part of this cost can be attributed to basic resistance to change within the firm [Rumelt (1995)]. Some of the cost might also come from the fact that there are plenty of routines in the organization and that these can be complementary, which implies that amending just one of them would be unwise and leaves the firm with no choice but to undergo large-scale reforms [Milgrom and Roberts (1994)]. One goal of environmental public policy could be to alleviate those cost factors, through such means as subsidized training and the diffusion of best business practices.

3. Risk reduction

Environmental regulation seeks not only to correct for ongoing negative externalities but also to prevent and deter accidental damages to Nature and human beings. The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), for instance, deals with cleanup costs following some environmental accident and specifies the responsibilities of involved parties. Such regulation surely affects the firms' efforts to reduce the risk of an environmental accident. Risk reduction activities, however, seem less likely to fit the Porter hypothesis, unless their bottom line is clear in the short run.

One channel that may yield tangible rewards for inventive actions that reduce the risk of environmental accidents is liability insurance. Insurance contracts usually ask lower premium and deductibles from diligent firms. The financial payoff for those firms can be significant and gives them strong incentives to keep their risks under control. Lender's liability would also have the same effect. The regulator's intervention on those two markets – insurance and banking – might therefore yield an appropriate framework that would trigger socially beneficial innovations.

Another possibility for the regulator is to facilitate convergence on appropriate standards for environmental risk management systems. In some recent papers, I have proposed a stylized version of such a system that, once implemented, might enhance *both* risk reduction and regular business activities [Sinclair-Desgagné and Gabel (1997); Sinclair-Desgagné (1999); Boyer and Sinclair-Desgagné (1999)]. This scheme works as follows:

> Consider, for instance, a plant manager whose limited time and attention must be split between short-term returns and the reduction of long-term environmental risks. Denote the former and the latter task by A and B respectively.
>
> Assume that the manager's performance on task A is regularly monitored through the firm's accounting system. Performance on task B, on the other hand, will be audited only if performance on task A is high.
>
> Now, let incentive pay be set such that the manager's expected utility (or satisfaction) is higher when an audit takes place than when no audit occurs. However, if an audit yields a bad assessment of performance on task B, then the manager's ex post compensation will be inferior to what it would have been if no audit had taken place.

The intuitive reason why this scheme could help overcome what is usually seen as a strict tradeoff between financial returns and long-term risk reduction is straightforward. Under the above scheme the manager would like to be audited. She would then be lead to spend more effort on task A, in order to increase the likelihood of showing high performance on this task and triggering an audit. But since there is no benefit to be audited if performance on task B is ultimately assessed to be low, she would be lead to work harder as well on task B. This means that the respective efforts expended on tasks A and B have now become *complementary* from the viewpoint of earning higher payoffs. If this complementarity is strong enough, it will alleviate current demands on managerial time and favor the creation of synergies between financial and environmental duties.

This scheme relies on internal audits. The regulator's can be quite helpful in harmonizing practices of environmental auditing and therefore lower its cost, as shown by the success of the the ISO 14000 and the EMAS standards. The benefits of harmonization can be non-negligible: for example, Ciba Clayton took three man-years to establish the eco-management system at its first registered site in the United Kingdom, including time talking with other companies regarding the requirements of the then-nascent standards; the company estimates that the time would be cut by two-thirds under the final version of EMAS. Furthermore, standardized auditing practices, because they make audit results comparable and credible, are essential for the above win-win management system to be implemented.

4. Radical innovations

The fact that well-crafted environmental regulation might trigger not only incremental (low-hanging fruits) but also radical innovations is probably the most appealing and controversial version of the Porter hypothesis.

Such a proposition was analyzed formally in Cadot and Sinclair-Desgagné (1995a and b). We consider the problem of a small-country government balancing a desire for stricter environmental standards against a concern for the competitive position of home firms. The government ends up using the *threat* of imposing the best available cleaner technology as the basic incentive device. Regulation at one time period is always uncertain, but the probabilities of regulation tend to decrease over time, as the firm successfully completes intermediate stages of the technology-development process. As the private return to technology development increases, the probability of regulation goes down, i.e. incentives become softer and the probability of completion increases. Therefore, the inefficiency associated with a positive probability of regulation is minimal for the best projects. As the government's preference for immediate regulation – a proxy for environmentalist pressure – increases, the firm's probability of successful development, which of course depends on the firm's efforts, goes up. As the government's preference for successful development of a domestic cleaner technology – a proxy for industrial policy concerns – increases, the firm's probability of development goes down.

This model was inspired by the case of Peugeot SA, the French car maker, and the lean-burn engine [Gabel (1991)]. While automobiles sold in the United States have had to be equipped with anti-pollution devices for many years as a result of gradual tightening of the 1970 Clean Air Act, progress towards a reduction in automobile emissions has been slower in Europe. All automobiles sold on the American market have to be fitted with three-way catalytic converters that convert hydrocarbons into CO_2 and water and reduce nitrogen oxide emissions at the engine's exhaust.

Catalytic converters are efficient ways of reducing pollution provided that the engine is hot enough; the downside being the amount of pollution released before the engine heats up, increased fuel consumption, and the necessary maintenance cost of the equipment. By contrast, Peugeot SA (as well as Ford of Europe) have pursued during the 80s the development of an alternative technology called the "lean-burn" engine. A different design allows lean-burn engines to run on higher air/fuel ratios than conventional ones, thus saving on fuel consumption and reducing at the same time carbon and nitrogen oxyde emissions at the source. In the late 1980s, the French government was facing a tradeoff similar to the one we modelled: on the one hand, there was growing pressure from environmentalists lobbies and important trade partners like Germany to adopt stricter standards on car emissions (German car manufacturers had already adopted the catalytic converter), on the other hand, Peugeot SA, one of the country's major employer, was just completing a painful turnaround and had a head start on a the development of a better technology.

As one knows ex post, the development of the lean-burn engine was not successful: after delaying compliance with European norms for many years, France finally had to impose them on its car makers, which killed Peugeot's development efforts. This case and the model yield nevertheless some interesting conclusions concerning the role environmental regulation can play in triggering radical innovation. First, contrary to common wisdom, regulation based on the best available technology might not deter innovation ex ante, provided it is first raised as *a credible threat.* The use of such threats by the regulator, however, requires foresight and commitment beyond current government mandates.32 Secondly, regulators that care too much too openly about domestic competitiveness rather than about environmental depletion are taken hostage by the firms, and this slows down radical innovation.

32 For the problems linked to these requirements, see respectively Mello-e-Souza (1993) and Boyer and Laffont (1999).

Concluding remarks

This paper discussed the plausibility of the so-called Porter hypothesis - that strict environmental regulation can contribute to increase both social welfare and firm's profitability by giving the latter incentives to innovate. The hypothesis *cannot* be rejected on theoretical ground, unless one sticks to a very narrow view of neoclassical economics. The regulations most likely to fit the hypothesis and yield win-win situations depend on the type of innovation that is pursued - incremental (low-hanging fruits), risk reducing or radical. To enhance the discovery of low-hanging fruits, the regulator should not only enforce environmental standards that are strict in their objectives but flexible respective to the means, it should also contribute to lifting current obstacles to reengineering practices within the firm. The latter requires a systemic view of the corporate landscape in order to uncover all factors of organizational inertia *and* especially their *complementarities*. Innovations in the reduction of major environmental risks can arise most likely if one *overcomes tradeoffism*, i.e. the current view held in most firms that dealing with risks involving small probabilities (of large damages) always means sacrificing some short-run financial returns. The regulator can contribute to this by supporting new standards for environmental auditing and management systems that would render possible the implementation of win-win incentives and control schemes like the one sketched in section 3. Finally, radical innovation often presupposes a shift of paradigm on the part of firms and researchers. The regulator can promote and accelerate the right shift through persistent *selective intervention* (instead of uniform policies) that favors well-managed and environmentally-friendly firms.

References

Bolton, Patrick and Mathias Dewatripont, "The Firm as a Communication Network," *Quarterly Journal of Economics* 109 (1994), 809-839.

Boyer, Marcel and Bernard Sinclair-Desgagné, "Corporate Governance of Major Technological Risks," in Henk Folmer, Shelby Gerking and Adam Rose (eds.), *Frontiers in Environmental Economics*, Edward Elgar, 1999 (forthcoming).

Boyer, Marcel and Jean-Jacques Laffont, "Toward a Political Theory of the Emergence of Environmental Incentive Regulation," *Rand Journal of Economics* 30 (1999), 137-157.

Cadot, Olivier and Bernard Sinclair-Desgagné, "Environmental Standards and Industrial Policy," *Journal of Environmental Economics and Management* 29 (1995a), 228-237.

____________, "Innovation under the Threat of Stricter Environmental Standards," in Carlo Carraro, Yiannis Katsoulacos and Anastasios Xapapadeas (eds.), *Environmental Policy and Market Structure*, Kluwer, 1995b.

Cyert, Richard and John March, *A Behavioral Theory of the Firm*, 1992 (second edition), Blackwell.

Environmental Law Institute, 1999. Winning from Innovation: Perspectives on Business, Policy and Legal Factors that May Affect the Porter Hypothesis. Washington D.C. (February).

Gabel, H. Landis, "European Exhaust Emission Standards for Small Cars," INSEAD Case Study, 1991.

Gabel, H. Landis and Bernard Sinclair-Desgagné, "Standard Business Procedures and Environmental Public Policy," in Henk Folmer, Shelby Gerking and Adam Rose (eds.), *Frontiers in Environmental Economics*, Edward Elgar, 1999 (forthcoming).

____________, "The Firm, its Routines, and the Environment," in Tom Tietenberg and Henk Folmer (eds.), *The International Yearbook of Environmental and Resource Economics: A Survey of Current Issues*, Kluwer, 1998.

____________, "Corporate Responses to Environmental Concerns," in Henk Folmer, H. Landis Gabel and Hans Opshoor (eds.), *Principles of Environmental and Resource Economics : A Guide for Students and Decision Makers*, Edward Elgar Publishing, 1995 (first edition) and 1999 (second edition; forthcoming).

____________, "Environmental Auditing in Management Systems and Public Policy," *Journal of Environmental Economics and Management* 33 (1997), 331-346.

____________, "From Market Failure to Organizational Failure," in Robert Welford and Nigel Roome (eds.), *Business and the Environment*, European Research Press, 1994.

____________, "Managerial Incentives and Environmental Compliance," *Journal of Environmental Economics and Management* 24 (1993), 229-240.
Gibbons, Robert, "Incentives in Organizations," *Journal of Economic Perspectives* 12 (1998), 115-132.

Gimpel, Jean, *La révolution industrielle du Moyen-Âge*, 1975, Éditions du Seuil.

Holmstrom, Bengt and Paul Milgrom, "Multi-Task Principal-Agent Analysis: Incentive Contract, Asset Ownership and Job Design," *Journal of Law, Economics and Organization* 7 (1992; special issue), 24-52.
Lanoie, Paul and Georges A. Tanguay, "Dix exemples de rentabilité financière liés à une saine gestion environnementale," CIRANO Working Paper 98s-05, 1998.

Mello-e-Souza, Carlos Alberto, "Mortal Managers and Long-Term Goals: An Impossibility Result," *Rand Journal of Economics* (1993), 313-327.

Milgrom, Paul and John Roberts, "Complementarities and Systems: Understanding Japanese Economic Organization," *Estudios Económicos*, 9 (1994), 3-42.

_____________, *Economics, Organization, and Management*, 1992, Prentice-Hall.

Palmer, Kurt, Wallace E. Oates and Paul Portney, "Tightening Environmental Standards : The Benefit-Cost or the No-Cost Paradigm," *Journal of Economic Perspectives* 9 (1995), 119-131.

Porter, Michael E., "America's Green Strategy," *Scientific American*, 1996 (April).

______ and Claas van der Lind, "Towards a New Conception of the Environment-Competitiveness Relationship," *Journal of Economic Perspectives* 9 (1995), 97-118.

Radner, Roy, "Hierarchy: The Economics of Managing," *Journal of Economic Literature* 30 (1992), 265-298.

Rosenberg, Nathan, *Inside the Black Box : Technology and Economics*, 1982, Cambridge University Press.

Rumelt, Richard, "Inertia and Transformation," in Cynthia Montgomery (ed.), *Resource-Based* *and Evolutionary Theories of the Firm*, Kluwer, 1995.

Sah, Rajiv K. and Joseph Stiglitz, "The Architecture of Economic Systems: Hierarchies and Polyarchies," *American Economic Review* 76 (1986), 716-727.

Segerson, Kathleen and Tom Tietenberg, "The Structure of Penalties in Environmental Enforcement," *Journal of Environmental Economics and Management* 23 (1992), 179-200.

Sinclair-Desgagné, Bernard, "How to Restore Higher-Powered Incentives in Multi-Task Agencies," *Journal of Law, Economics, and Organization* (June 1999), forthcoming.

____________, "La mise en vigueur des politiques environnementales et l'organisation de la firme," *L'Actualité Economique* 70 (1994), 211-224.

________ and Antoine Soubeyran, "When is deliberation needed?," Unpublished manuscript, CIRANO, March 1999.

Tirole, Jean, "Corporate Governance," 1998 Presidential Address to the Econometric Society, to appear in *Econometrica.*

C. The Next Bottom Line: Making Sustainable Development Tangible

Presentation by Robert Day, World Resources Institute

The Next Bottom Line

Making
Sustainable Development
Tangible

Robert Day

World Resources Institute

World Resources Institute(WRI)

- WRI: Washington, DC based environmental policy research organization.

- WRI's SPLASH project works directly with companies to affect private choices and promote sustainable development.

  DuPont, Monsanto, Weyerhaeuser, GM, BP, and others.

- SPLASH is in the process of expanding its partnerships.

- **"The Next Bottom Line: Making Sustainable Development Tangible"** released at WRI's Sustainable Enterprise Summit, Washington DC, October 21-22 '98.

The Next Bottom Line: Overview

- A Business Agenda for Sustainable Development
- Four Business Drivers
- Driving Innovation
- Getting Started

A Business Agenda for Sustainable Development

Every company we work with is wrestling with the concept of "sustainable development" and trying to make it relevant. In the end, real change will not occur unless it is profitable.

Winning opportunities for business leadership in sustainable development:

- **Replacing material with information**
- **Valuing ecosystems**
- **Connecting with the community**

World Resources Institute 4

A Business Agenda for Sustainable Development

Replacing Material with Information:

Although substantial gains have been made in energy and resource efficiency, the global economy is still very inefficient at converting material into products and services.

Even in the most modern and efficient industrial economies, the annual material requirements per person total between 45,000 and 85,000 kilograms -- the weekly equivalent of 300 shopping bags full of stuff.

World Resources Institute 5

A Business Agenda for Sustainable Development

Replacing Material with Information:

The key to resource productivity lies in making creative use of knowledge to drive resource use down and the value to a customer up.

Old	New
Volume Intensity	Knowledge Intensity
Volume Output	Value per Volume Output
Capital Invested	Value per Capital Invested
Material Throughput	Material Per Customer Served
Virgin Material and Energy	Recovered Material and Energy
Focus on Product	Focus on Function

World Resources Institute 6

A Business Agenda for Sustainable Development

Replacing Material with Information:

Examples:

• *DuPont-Ford UK:* Customer relationship is changed to take advantage of DuPont's knowledge of automotive paints.

~8% annual material savings / year
DuPont's market share grows from 25% to 75%

• *"Electric paper":* Xerox PARC is developing a bi-stable display that will store images without needing a power source, work like newsprint, and be reusable up to a million times.

A Business Agenda for Sustainable Development

Valuing Ecosystems:

Virtually none of the services provided to our economy by ecosystems are valued (ex: clean water, clean air, climate).

The economic value of ecosystem services was recently estimated at about $33 trillion per year.*

World Resources Institute 8

A Business Agenda for Sustainable Development

Valuing Ecosystems:

Some opportunities:

- Offsetting degradation from other operations

    ex: nonpoint pollution trading; Weyerhaeuser

- Using nature to reduce operational costs

    ex: Ethel M. Chocolates' "Living Machine"; Wal-Mart

- Creating new business around restoration

    ex: carbon sequestration; watershed protection

World Resources Institute 9

A Business Agenda for Sustainable Development

Connecting with the Community:

By engaging their various communities, companies can learn specific opportunities to enhance both human lives and their bottom line.

- Access to basic education for everyone in the world would cost an estimated $6 billion annually.
- Universal access to water and sanitation would cost $12 billion annually.
- Basic health and nutrition for all would cost $13 billion annually.

- Americans spend $8 billion annually on cosmetics.

A Business Agenda for Sustainable Development

Connecting with the Community:

By learning with their communities, companies can reduce their risk from "hot button" issues and/or open new business opportunities.

Some examples:

• Local communities	*S.C. manufacturing plant*
• Regions and countries	*AES*
• Employees	*Herman Miller*
• Investors	*Baxter International*
• Competitors	*DuPont Films*
• NGOs	*WRI -- SCSB*

Four Business Drivers

The WRI Business Value Model

Business Value:	Right to Operate	Cost Reduction	Customer loyalty	New Markets
Action:	- Waste Treatment - Compliance	- Pollution Prevention - Yield Improvement	- Design for Environment - Service Intensity	- Environmental Restoration - Social Reconstruction - Step Change - Business Redefinition
Organizational Lead:	Public Affairs / General Counsel	Manufacturing / Operations	R&D / Design Engineering / Marketing	Strategic Planning / Marketing

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Four Business Drivers

Right to Operate:

The first and most basic reason to protect the environment and worker health and safety is to comply with legal requirements or social pressure.

Businesses with solid reputations also:
- Recruit the best people
- Enjoy privileged access to new markets
- Generate greater trust from governments and civic leaders.

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Four Business Drivers

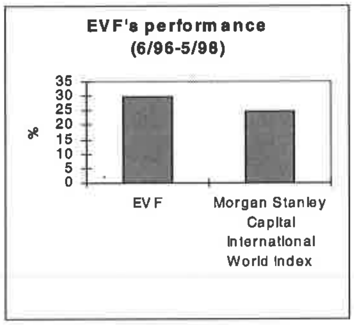
Cost Reduction:

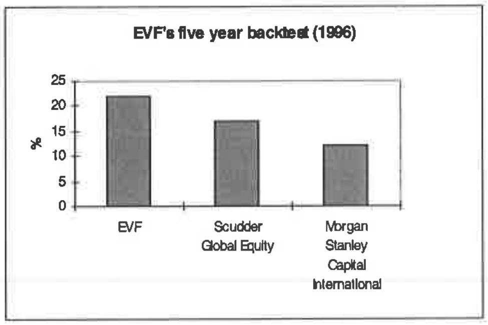
- Avoidance of waste treatment and disposal
- Raw material reductions
- Process quality improvements

Four Business Drivers

Cost Reduction:

"Eco-efficiency" funds, such as the Scudder-Storebrand Environmental Value Fund (EVF) invest in best in class companies across global industries, and early results are encouraging.





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Four Business Drivers

Customer Loyalty:

When a business builds environmental benefit into products, it creates direct value to the customer.

- The benefit reduces the customer's environmental burden.

- The search for the environmental benefit often yields enhancements to: Product performance, Cost, Quality, Safety, Serviceability

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Four Business Drivers

Customer Loyalty:

Successful approaches, in ascending order of difficulty and level of investment needed:

1. Service Add-ons	*DuPont Sulphur*
2. Product Modification	*Kodak Single-Use Camera*
3. From Product to Offering	*BP Solar*
4. From Selling to Leasing	*Xerox ARM*
5. Moving Toward the Customer	*DuPont-Ford UK*

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Four Business Drivers

New Markets:

What will be "the next big thing?"

• Sustainable Development can be used as a framework through which to identify *"market discontinuities"* -- conflicts between major trends.

• Companies can use this knowledge to develop new markets for entirely different streams of technologies and services that substitute knowledge for material, restore ecosystems, and connect people.

Getting Started

Six Key Organizational Success Factors

- Leadership
- External Engagement
- Measures
- Strategic Intent
- Shortening the Value Chain
- Adaptive Culture

Getting Started

Leadership: Commitment Across the Company

Building a business commitment to sustainable development requires
- new technology, products and services;
- changes in value and behavior; and
- new relationships with customers and suppliers.

Such a commitment must involve leadership at all levels and in all functions for meaningful change to occur.

- Most important are:
  - environment, health and safety staff
  - marketing
  - CEO and CFO
  - operations
  - business unit managers

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Getting Started

External Engagement: Learning from Different Perspectives

Companies that aspire to sustainable development recognize that they cannot answer many essential questions without the help of outsiders.

Template for getting connected:

- Develop the business case for purposeful connections.
- Inventory and evaluate existing associations and partnerships.
- Identify important gaps, vulnerabilities, and opportunities.
- Evaluate potential partners, associations, and memberships.
- Establish a small number of associations or partnerships.

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Getting Started

Measures: Making Better Informed Decisions

Measures are critical to monitor environmental and social progress, to engage senior management, and for reporting.

Four Key Categories of Environmental Performance Measurement:

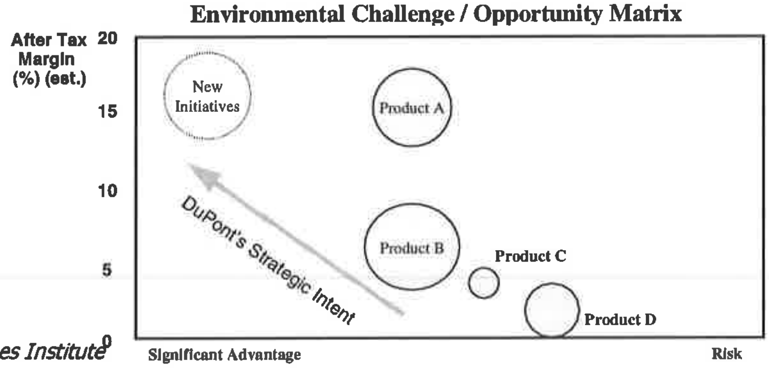
- Materials Use
- Energy Consumption
- Nonproduct Output
- Pollutant Releases

Getting Started

Strategic Intent: From Stewardship to Strategy

Segregated environmental programs cannot fundamentally alter the environmental or social footprint of a company. Environmental performance must become a key part of strategic planning.

Environmental Challenge / Opportunity Matrix



Getting Started

Strategic Intent: Three Schools of Management

	"Harangue"	"Tools"	"Integration"
Characteristics	Exhortation, lots of talk about "environment" and"sustainability."	Introduction of specific tools (eg: LCA, DfE)	Serious review of all elements of the organization
Rationale	"Everybody's doing it," or "We're already o.k."	Customers insist, or competitors loom	Systematic efforts to improve earnings
Responsibility	Unchanged	Lower-level management	Shared responsibility
Structural Changes	None	Incremental changes	Dramatic changes
Reaction	"The flavor of the month"	"Nice idea, too bad upper management is not serious about it."	"At last, we've got a chance to do it right."

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Getting Started

Shortening the Value Chain: Efficiency and Revenue Growth

A value chain is most efficient when there are few transactions between producers and their final customers.

- Shortening the value chain can help capture the customer interface.
- Companies can use information about customer needs to design greater efficiency into the system and capture savings.

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Getting Started

Adaptive Culture:
Allowing People to Give Their Best

Systems thinking, shared visions and team learning spur innovation

Lessons from the Adaptive Culture movement:

1. Work that is challenging and complex inspires employees to maintain enthusiasm and productivity.
2. Framing challenges as outcomes, not tasks, allows employees to be more goal-oriented and driven.
3. The values-driven (and open) workplace is more productive than one run purely for financial return.

Getting Started

Benchmarking Progress:

Some questions to ask…

Leadership
Do stars in your company lend credence to sustainable development?
How many senior leaders push this issue?
Are leaders from across the company deeply involved in the effort?

External Engagement
What NGO partnerships are you involved in?
What new products have emerged from external engagement?

Measurement
What do you measure?
Who sees it?
Who uses it?

Getting Started

Benchmarking Progress:

More questions...

Strategic Intent
Is Sustainable Development a part of any business planning process?
Does the business value of environmental and social investments get measured?
How would you characterize your company's approach: Harangue, Tools, or Integration?

Shortening the Value Chain
Do you engage customers and suppliers? Competitors?
Are you bringing yourself closer to the customer in any business?

Adaptive Culture
What are you doing to involve employees at all levels in Sustainable Development?
Do you have an empowered, risk-taking culture?
Is Sustainable Development a factor in recruitment?

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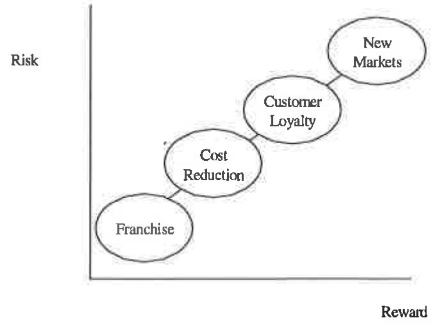
Driving Innovation

"If anyone can do it, why are so few actually pursuing new product and market development?":



Although the rewards for customer loyalty and new markets directed activities can be great, the risk is also significant.

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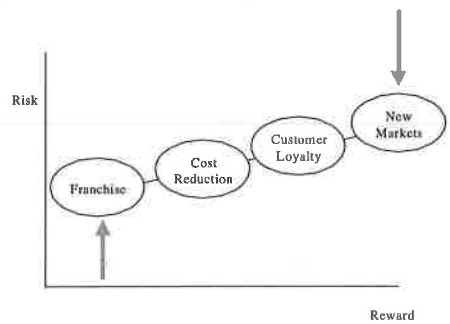
Driving Innovation

"So why should we begin pursuing these opportunities now?":

• *Resource constraints are making franchise protection more complex and risky.* (ex: Shell -- Brent Spar, Nigeria)
• *Market discontinuities are becoming clearer, lowering long-term risk for SD market and product development.*



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Driving Innovation

<u>More efficient "business as usual" will not suffice:</u>

• Total material, energy, and natural resource use continues to rise, even in the face of tremendous efficiency gains.

• Process efficiency alone will never achieve sustainable development. Without technological change, process efficiency simply gets us where we are going faster.

"Energy conservation lowers the real price of energy and thus induces an energy demand expansion."
- David Pearce, Britain's leading environmental economist

Driving Innovation

The innovation imperative:

- From 1975 to 1995, 60% of Fortune 500 companies disappeared from the list.

- Research by Kim and Mauborgne (Insead):

Out of more than 100 new business launches:
86% were "me too" launches or incremental improvements.

The remaining 14% (which created new markets) generated:
- 38% of all revenues
- 61% of profits