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Theoretical perspectives on strategic environmental management*

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Abstract. Strategic Environmental Management (SEM) incorporates into firms' core strategies the transformation of products and processes that they believe an environmentally concerned society will increasingly demand. Significant threads have to do with the discovery of cost savings and market opportunities from reducing environmental impacts. SEM, like the environmental regulation hypothesis associated with Michael Porter, implies that society's efforts to reduce external environmental costs often lead to identification of hitherto-ignored or undeveloped profit possibilities. This would be surprising from the standpoint of neoclassical economic theory, to the extent that SEM utilizes available information about the potential costs and benefits of projects. Within the framework of evolutionary, capabilities-based theories of the firm, however, this discovery and its exploitation in SEM make perfect sense. Capabilities theory would imply that firms' intrinsic path dependence may previously have obscured such opportunities. This paper examines the theory of SEM, its implications for neoclassical and capabilities theories of the firm, and survey results drawn from the author's work with member companies in a regional pollution prevention roundtable.

Key words: Environment – Management – Capabilities – Firms – Innovation

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1 Introduction

Strategic Environmental Management (SEM) has emerged during the past decade and a half as an important business practice worldwide. Its premise is that firms can uncover profit opportunities– by cutting costs and/or boosting revenues– in the course of reducing their environmental impacts. SEM seeks to harmonize environmental and bottom line goals by integrating impact-reducing product and process design into companies' core strategic visions. But if corporate greening or individual SEM projects need not entail a cost burden, and can increase profitability in many, non-exceptional cases, then pre-SEM practice may have ignored available profit opportunities. Such behavior would run counter to a neoclassical theoretical framework, within which firms make rational use of all available information to maximize profits (see Gabel and Sinclair-Desgagné, 1997, for a prior statement of the problem). On the other hand, evolutionary economics-within which firms' *organizational capabilities* evolve over time in idiosyncratic ways, and operate (through routines and tacit knowledge) upon only a fraction of the information that is ostensibly available-offers a systematic approach to understanding SEM rather than dismissing it.

This paper examines the implications of SEM with respect to these alternative theories of the firm, and brings to bear survey results from a sample of environmental management projects for empirical evidence on these implications. The survey cases allow us to ask to what extent the range of behaviors observed can be comfortably explained within a neoclassical framework, in which boundedly rational decision makers balance the expected costs and benefits of attempting to reduce environmental impacts, and whether a significant portion of that range might be more consistent with the kinds of scenarios predicted by evolutionary or organizational capabilities theorists. This class of SEM scenarios is closely related to the hypothesis associated with Michael Porter (1991, 1995, with van der Linde), that heightened environmental regulation might enhance competitiveness by inducing innovation. Thus the SEM survey evidence presented below also has implications for the Porter hypothesis, whose affinity with evolutionary or capabilities theory has not been widely noted (an exception is Jaffe et al., 2000).

Theoretical perspectives on SEM are important for corporate strategy and policy reasons. As will be demonstrated in what follows, if a neoclassical view of the firm is applied, then companies that act to reduce their environmental impacts should expect– most of the time, under most circumstances– to raise their costs and reduce profits. This presumption accords well with top corporate managers' traditional ways of understanding the economy-ecology nexus, and suggests viewing the claims of SEM practitioners with a great deal of skepticism. But viewed through the lens of theories of the firm that revolve around organizational capabilities, it will be argued, SEM may make perfect sense.

SEM needs to be situated within the context of changing societal approaches to reducing economic impacts on the environment, (for background, see Hall and Roome, 1996; Frankel, 1998; for a European focus, see Christie and Rolfe, 1995). The 1960s saw the emergence of widespread concerns about pollution and resource depletion arising from industrial processes. Early policy initiatives and corporate

practice revolved around end-of-pipe measures for pollution *control*. By the late 1980s, the scope and complexity of the problem, along with the costliness of pollution control solutions, led to a shift in focus toward pollution *prevention*: A small but growing number of companies began to reduce pollution at the source by changing production processes. With the shift toward process change came a widening belief that environmental impact reduction could go hand in hand with greater cost-effectiveness, and that firms could achieve and exceed regulatory compliance as a byproduct of thoroughgoing pollution prevention. Companies began to view impact reduction as a potential source of competitive strength. This perspective was strengthened by the recognition that some segment of demand in many markets had become sensitive to sellers' reputations for environmental performance.

By the early 1990s, SEM advocates began to explore potential routes to competitiveness based on redesign of products themselves, under rubrics like Life Cycle Analysis and Design for Environment. Product redesign has been aimed at reducing materials- and energy-intensity and pollution, across production, use, and post-usage disposal. It may involve design for easier disassembly and component reuse, remanufacturing, or recycling. It may also entail efforts to capture market demand when buyers seek low environmental impact goods and services. This kind of strategic positioning is what distinguishes SEM from earlier, more limited pollution prevention practices. In its most developed form, SEM links individual products and processes to a vision of systemic sustainability, which requires that the sum total of all individual activities not create environmental burdens exceeding the earth's carrying capacity.[1]

The opportunities for this kind of strategic positioning are thought to originate in broad social and environmental trends. Hart (1997) argues that while "bottom-up pollution-prevention programs have saved companies billions of dollars" (67-68)-with the increased cost savings and hence profits coming from reduced waste and energy use-the best is yet to come. He points to the smaller number of firms that have begun reorienting their long term strategies, and plans for revenue growth, around solving sustainable development problems in which their basic capabilities give them expertise. Driven by environment-development conflict, by tightening regulation, and by changing public perceptions, the demands of "sustainable development will constitute one of the biggest opportunities in the history of commerce" (71).

This SEM logic clearly runs counter to the traditional notion that economic and environmental gains pose an intrinsic tradeoff, with more of one necessitating less of the other. Porter (1991, 1995, with van der Linde) makes explicit the idea that with appropriate public policy and private sector strategic choices, the two can be complementary. Porter's argument is that tighter environmental regulations can stimulate innovation, which can reduce both ecological impacts and costs while enhancing companies' competitive position relative to nations with less stringent regulation. According to this line of reasoning, it is only within a short term, static

[1] For example, manufacturers might halve the environmental burdens imposed by each automobile, but population and income growth could concurrently quadruple the number of cars worldwide. In this case, sustainable development would require meeting the need for transportation services in ways not based solely on the individual car.

framework that increased social benefit (from reduced externalities) would imply greater private cost for producers.

SEM might be conceptualized as tighter regulatory policy at the corporate level, in which firms themselves target environmental impact reductions and increase the implicit price that decision makers ascribe to those impacts. The precepts of SEM dovetail closely with Porter's complementarity hypothesis because SEM presumes that once pushed in this direction by external or internal pressures, firms can strategically reposition themselves by relearning the design, production, and/or sale of their products along lower impact lines. How they and their industry cohorts did it before is not taken as necessarily uniquely best and most profitable; in fact, approaches to competitiveness that have worked in the past may even make it difficult to recognize new SEM profit opportunities on both the cost and revenue sides.

These assumptions of SEM suggest its theoretical kinship with the literatures on organizational learning (Garvin, 1993) and quality management (Deming, 1986). Indeed, many researchers and practitioners have emphasized that SEM is organizational learning and quality management as applied to environmental impact reduction (President's Commission on Environmental Quality, 1993). It has also been argued that the underlying ideas of organizational learning and quality management are more consistent with capabilities theories of the firm than with neoclassical concepts (Goldstein, 1997). While Jaffe et al. (2000) point out the correspondence between Porter's approach to regulation and these alternative theories of the firm, until now this theoretical connection has not been systematically examined with respect to SEM. The present study takes a first step in this direction, asking whether the principles and practice of SEM might fit better theoretically and empirically with a capabilities-based than with a neoclassical perspective on the firm. But first the latter must be specified, and the sources of its unease with SEM examined.

2 The neoclassical firm and SEM

Neoclassical theories of the firm can be characterized as sharing the following set of features. Individual decision-makers maximize well being in contracting with one another and with the company. The firm itself faces a production function that is well defined (at least in a probabilistic sense), allowing it to reach an equilibrium that maximizes profits subject to the constraints posed by its contractual and technological environment. If markets have been allowed to work freely, that equilibrium should be optimal for the company and its participants. The optimal contracts and technical choices would be expected to change only with a shift in some external condition upon which the initial maximization had been based.

This description is consistent with the familiar textbook model of the profit maximizing firm, and at the same time can incorporate the basic tenets of the more refined transaction cost-theoretic variant of the neoclassical theory. This version (Williamson, 1985) starts from the basic model and focuses upon a problem seen as critical to its specification: the difficulties of contracting when it is costly to gather relevant information. Authors working within this strand of neoclassical theory frequently describe the firm as a nexus of contracts, explicit and implicit,

bringing together the suppliers of the organization's factors and defining its choice of the optimal set of inputs and technique.

Given the limits and possibilities posed by its external surroundings, the firm envisaged as above will be doing the best that it can at any point in time. Subject to the constraints of costly contracting, it will be utilizing the best (profit maximizing) available technique. Management teams that fail to perform efficiently in this sense would be expected to be replaced; inefficient firms would be expected to disappear. Within this theoretical framework, it would be surprising to observe many companies proceeding for significant time periods making *ex ante* inefficient choices by failing to make optimal use of available information. It would be equally counterintuitive for a new managerial approach to arise that is capable of uncovering a class of profit opportunities that had been systematically underexploited. Yet that is precisely the premise of SEM.

The ability of SEM to deliver on its promise has been challenged by critics operating explicitly or implicitly within this neoclassical framework. Walley and Whitehead (1994), attacking the Porter hypothesis, reject the notion that the benefits of environmental management programs will often outweigh the costs. They recognize the existence of situations in which it is possible simultaneously to improve profits and environmental performance, but argue that such cases are the exception rather than the rule. The complexity of environmental problems means that "companies should seek to minimize the destruction of shareholder value that is like to be caused by environmental costs rather than attempt to create value through environmental enhancements" (47). Palmer et al. (1995) also take issue with Porter and van der Linde's purported vision of "a private sector that systematically overlooks profitable opportunities for innovation" (121). Starting from a standard neoclassical model, these authors naturally interpret the Porter hypothesis as implying gross inefficiency rather than a different perspective on how companies interact with the world around them. Similarly, Xepapadeas and de Zeeuw (1999) argue that firms do not have to be pushed to exploit existing cost saving opportunities; again, the focus is on tighter environmental regulation, but the argument applies equally to self-imposed SEM goals. And again, the conclusion is that better environmental performance may benefit society as a whole, but by the very nature of business decision making, must hurt individual companies' profitability in comparison to prior, higher-environmental impact practices.

It is important to emphasize that neoclassically rooted theory predicts not that observed outcomes would be best in a perfect world, but that they achieve an optimal balance between the gains from organizational change and the transaction costs of achieving it, given the underlying conditions. Milgrom and Roberts (1992) provide a sophisticated exposition of the general case; with respect to environmental management problems, Walley and Whitehead (1994) suggest that managerial decision making is hampered by the proliferation of possible solutions from which to choose. According to this argument, firms reject SEM projects because the expected costs of finding and assessing the available solutions outweigh the likely benefits. Conversely, a neoclassical analysis of observed SEM initiatives would look for changes in the firms' external conditions that might be seen as bringing about re-optimizing: Given changed market demand, available technologies,

or regulatory regime-each of which would generate a new set of relative prices-different environmental management practices might become profit maximizing (or loss minimizing, as in Walley and Whitehead's account). I return to this point at the end of the following section.

3 SEM and capabilities theory

Within the alternative set of capabilities-based theories of the firm, in contrast to the above, organizational changes enhancing both financial and environmental performance would not tend to be seen as necessarily responses to changed exogenous conditions or as aberrations. These theoretical approaches revolve around the firm's ability to do certain kinds of things well enough to make it competitively viable in producing related goods and services: its "organizational capabilities" (Chandler, 1977). Within this tradition, choice of technique is not a matter of selection from a menu of possibilities with known characteristics; rather, it is a combination of inheritance from past practice and ongoing learning about the possibilities of the present and future. The capabilities approach suggests that while existing capacities may equip companies for effective performance along certain competitive dimensions, other kinds of potentially profitable activity may fall outside their normal scopes of awareness, inquiry, or expertise. This paper's purpose is to explore the power of theories based on organizational capabilities in explaining the existence of profitable SEM opportunities that had previously been ignored or undiscovered, and the present section will develop this theme on a theoretical level. Capabilities theories may also be useful in understanding the closely related question of which firms become SEM adopters and which do not; while this issue will necessarily be touched upon here, a fuller consideration must await further research.

Authors working within this framework have emphasized that the creation of business capabilities involves investment over time in physical, human, and organizational capital. Even within the range of practices for which its basic capabilities equip a firm, there is no presumption that it chooses a behavior that could be considered "optimal"; the fundamental uncertainty of its environment and the firm's own intrinsic limitations in processing information from that environment mean that companies "satisfice," not pursuing alternatives as long as things go "well enough," as suggested in the behavioral approach initiated by Simon (1955). All of these features make capabilities theory a useful lens through which to study the emergence of SEM as an approach to competitive position, because they offer clues about why SEM-type opportunities may exist unrecognized, why some firms rather than others might come to recognize them, and why such opportunities might persist even for experienced SEM practitioners.

The idea that firms evolve rather than continually reinventing themselves as neoclassical maximizers is due to Nelson and Winter (1982). In their evolutionary theory of the firm, technologies and market strategies are forged in a context of true uncertainty. Facing poorly defined sets of possible goals and ways of accomplishing them, business organizations develop and rely upon "routines" (Chapters 1 and 5): working patterns for seeking out information and translating it into particular kinds of action. A company's routines work like an organism's genes, both reflecting the

past evolution of its capabilities and limiting its range of feasible responses to its present environment. Organizational evolution thus exhibits path dependence; at any point in time, firms differ due to not only their current choices but also their histories.

Capabilities theory would suggest that the preponderance of environmentally damaging processes and products economy- or industry-wide is an inheritance from a past in which ecosystem externalities were poorly understood or ignored by regulators and customers. Firms often stay with these practices not because alternatives are unavailable or costlier, but because they are conditioned to do so. Some companies remain committed to those inherited processes and products, and perceive environmental issues strictly in terms of costly regulatory compliance. Others have forged significant new capabilities based on seeking out exploitable economy-ecology complementarities, but inevitably still confront high-environmental impact activities embedded within their routine structures. Even when profitable alternatives are well known, the weight of existing producer and customer routines for purchasing, marketing, testing, R&D, and regulatory reporting may serve to "lock in" an entire industry's old way of doing things (David, 1985).

Companies that do become SEM innovators may, as suggested by neoclassical theory, face particular regulatory or customer pressures. But capabilities theory offers a useful approach to understanding why and how some firms respond to those pressures along the path of SEM, rather than resisting them with legal or lobbying or marketing tactics, or deflecting them by means of end-of-pipe pollution control.[2] Some businesses' existing capabilities may predispose them toward an SEM route. The capability may be in reducing the materials content of a whole class of products. Prahalad and Hamel (1990, p.81) give the example of miniaturization in consumer electronics; an SEM application would be Japanese automakers' long standing focus on smaller, more fuel efficient cars and Toyota's and Honda's ensuing market leadership in hybrid gasoline-electric engines. Evolutionary theory also helps understand how SEM can emerge from a polluter's initial confrontation with public pressure. An important capability is quickly and effectively learning the changing needs of customers and translating that knowledge into product and process changes; Chandler (1977, pp. 410–411) gives an historical example from the heavy equipment industry. The paper industry honed such a capability in relation to its environmental practices, as early public concern about effluents led to companies' heightened strategic focus on responsiveness to related customer and governmental concerns. This sensitivity in turn has opened up a variety of competitive adaptations over the years, ranging from sustainable forestry to manufacturing process chemistry.

[2] In practice, the same company may both practice SEM and resist environmental regulation. U.S. automakers, for example, have developed significant environmental components in their competitive strategies while at the same time expending considerable resources fighting fuel efficiency and atmospheric particulates standards. The point is that there is a tension between these dynamics, and the greater a firm's investment and expertise in one direction the less relatively attractive are the payoffs it expects from the other.

This evolutionary tendency of capability building to become a self-reinforcing process can help explain the shift from pollution control to pollution prevention,[3] and changes in paper making are a good case study. Early clean water standards led firms in the industry to spend millions cleaning up effluents created by existing production technologies. As these capabilities developed, the companies learned a great deal about the sources, chemistry, and costliness of their water pollution. This knowledge then combined with the industry's evolving stakeholder relationships to move firms into searching for alternative technologies that would reduce pollution at the source. A result has been the emergence of chlorine free paper bleaching, which not only reduces end-of-pipe cleanup but has also proven valuable in terms of product characteristics and market demand (Maynard and Shortle, 2001; Vames, 1998).

This example highlights the interplay in SEM between the marketing, product design, process engineering, and pollution control functions. Capabilities theorists have suggested the importance of such horizontal information flows among the firm's disparate functions, both in effecting existing routines and in developing new ones (Aoki, 1990). A company seeking to create SEM-related capabilities or project applications must learn its existing environmental impacts and what causes them; because routines operate largely on the basis of tacit knowledge (Nelson and Winter, 1982), the nature and precise sources of these impacts may not be obvious. In addition, problems appearing at one stage of the design-purchasing-production-sales-customer use cycle are inevitably related to processes occurring at other stages. Thus problem solving requires creation of relationships permitting knowledge transfer across these functional lines. Capabilities theory emphasizes that it is the information *flow* rather than the pieces of information or individuals purveying it that is critical. The capacity to locate, interchange, and exploit information is always embedded in a particular organizational context. In the foregoing paper industry example, creating this context for cross functional knowledge flows, so that the environmental function was integrated across the others rather than isolated, underlay the transition from pollution control to pollution prevention.

The firm's history, structure and culture indelibly imprint its utilization of information; the mere availability of information about SEM, or about possible solutions to a particular impact reduction problem, does not ensure that a given company will act upon it. Although SEM capability building can become a self-reinforcing process and reduce the cost of each successive application, even experienced SEM practitioners will, as suggested by evolutionary theory, be operating on a relatively narrow base of information about the sources of and alternative solutions to specific environmental problems. Thus self auditing is common in SEM, whether it is broadly focused or aimed at changing a particular process, and is necessitated by the tacit nature of the knowledge underlying the firm's routines. Cross functional investigation of the sources of quality defects, employed in Total Quality Management, is a closely related phenomenon, and one that is equally at home within a capabilities-theoretic framework (Goldstein, 1997). Indeed, companies with highly developed TQM capabilities have often become SEM leaders, with the former natu-

[3] I am grateful to a reviewer for this journal for pointing out this connection.

rally encouraging the evolution of the latter competencies (President's Commission on Environmental Quality, 1993). For example, cross functional information flows and problem solving underlie the Design for Environment and Life Cycle Analysis SEM approaches discussed in Section 1. Evolutionary theory views firms' acquisition of useful information as intrinsically problematic, and the process is always specific to a particular organizational context and history.

The overlaps and contrasts with neoclassical theory here are worth elaborating, because they are relevant to the problem of deriving empirical predictions. As noted earlier, neoclassically based approaches like Williamson's transaction cost framework make extensive use of the idea that decision makers are rational but the rationality is bounded by the costliness of information. Here the focus is on the characteristics of the information, not of the decision maker. Simon recognized the importance of this distinction early on, arguing that actors' "approximations. . . may not be the best-even at the levels of computational complexity they are able to handle" (1955, p.101). He later responded to evolving neoclassical theory by arguing that models with balancing of marginal search costs and benefits deal with "the relationship of the actor to his environment. Hence, while these theories retain, in one sense, a classical picture of man as a maximizer, they clearly require considerable information about the characteristics of the actor, and not merely about his environment" (1959, p. 270). That requirement is precisely what Simon believed neoclassical theory ignores, with its presumption of optimal use of available information (including about expected search costs and benefits). He argued that even the metaphor of a filter is misleading; the "filtering" inevitably involves "attention to a very small part of the whole and exclusion, from the outset, of almost all that is not within the scope of attention" (272). *Focus* would perhaps be a better metaphor.

Here we have at least a partial distinction: The logic of a neoclassical framework with bounded rationality suggests firms in an industry employ very similar filters in dealing with costly information, and that profit-enhancing SEM would follow from some external change that changes the expected costs and benefits of the effort. But even lacking such change, evolutionary capabilities theory suggests that how firms focus on the world is more idiosyncratic and that hence SEM, by changing "the scope of attention," might quickly lead to identification of previously ignored profit opportunities. The distinction is only partial because externally arising pressures may reveal profit opportunities that hypothetically were easily available all along, not just given the external changes, and such cases may be consistent with either theory. Nevertheless, it is true that the precepts of SEM and the related Porter hypothesis have appeared wrong-headed to many analysts looking through a neoclassical lens, while on theoretical grounds, the capabilities approach seems to make good sense of these propositions. The following section further addresses these issues by specifying a set of purported linkages between SEM and profitability, and using them to generate empirical predictions-based on either neoclassical or capabilities theory-about firms' environmental management practices.

4 Propositions about SEM adoption

The asserted ties between SEM and increased profitability are at the center of the questions posed in this paper. When companies pursue these links, under what circumstances can their actions be explained by capabilities and neoclassical understandings of the firm? The SEM-profitability linkage can be analyzed in terms of five, interrelated claims. All take as given some regulatory structure.

1. Environmental impacts are clues to economic waste. Both pollution and resource depletion can be reduced by using inputs more fully and efficiently. DeSimone and Popoff (1997) argue that a key benefit of SEM is "resource productivity: doing more with less" (2). Cutting waste and emissions means fuller use of inputs, which-along with reduced materials and energy usage-increases profits.

2. SEM reduces other, often hidden environmental costs. Coping with customer, community, and regulatory environmental demands can be expensive, with the expenses frequently allocated in accounting analysis to corporate cost centers that obscure their origins. Site studies, permitting, monitoring, remediation, community relations, and employee training may all create costs that ultimately trace back to poor environmental performance (DeSimone and Popoff, 1997, p. 26). SEM expenditures that improve this performance, then, will induce savings beyond those directly achieved in the process or product changes at which the expenditures are targeted directly.

3. SEM may spur technical innovation. Porter and van der Linde (1995) deal with this primarily on a systemic level, with environmental regulation encouraging innovation industry- or economy-wide. But the logic applies equally to SEM programs adopted at the individual company level. Firms voluntarily setting high environmental standards may stimulate the emergence and/or diffusion of new ways of doing things that are both economically more efficient and environmentally less harmful.

4. SEM can capture new market opportunities. Companies may profit by recognizing and meeting demand for environmental impact-reducing products. This may be accomplished either by introducing new products, or by publicizing production process-related environmental improvements to better position the company with customers (Piasecki, 1995, Chapter 4).

5. SEM may encourage better management in general. In one respect this is an umbrella under which each of the above linkages could fit, since anything that could enhance competitiveness is presumably done better by better managed companies. But if profitability is a function of the capacity to systematically uncover sources of inefficiency, of cross-functional problem solving capable of integrating considerations from product design to production to sales, and of effective incentives for employees' participation in these processes– then getting better at doing SEM could make companies better at doing business in general (Petts et al., 1998).

These five potential channels to increased profitability are distilled from the SEM literature. What *a priori* expectations would the neoclassical and evolutionary capabilities theories of the firm suggest about the kinds of scenarios in which

we would observe companies pursuing these SEM routes to higher profitability? A standard way of dichotomizing the two theoretical frameworks' empirical predictions would be as follows. Neoclassical theory suggests that we would observe SEM-type changes following a shift in some external factor: the best available technologies, market demand-side preferences regarding environmental impacts, or the regulatory regime. Such a shift could induce re-optimization and a change in the optimal choice of processes and/or products. While a demand shift or new technology could generate a higher-profit outcome (by increasing revenue or lowering cost, respectively), tighter regulatory policy would be expected to reduce profitability by imposing new costs. Note that by this logic, a change in *internal* policy by virtue of SEM adoption generally would also be expected to decrease profits in the absence of *external* changes in demand or technology.

On the other side of this standard dichotomy, evolutionary theory would be taken to suggest that tighter external regulation (as in the Porter hypothesis) or adoption of SEM internally (as in the present study) could induce discovery of more profitable technique and/or product mix. This outcome would be possible because firms that have relied upon a set of learned routines, based on their histories and what has worked in the past, may be stimulated to change focus and find something that works even better. Of course, demand and/or technology changes as above could also induce such a change.

Jaffe et al. (2000) employ the foregoing dichotomy in discussing approaches to technical innovation (or diffusion) induced by regulatory tightening, i.e., the Porter hypothesis. They argue that in "the neoclassical theory. . . if firms are choosing [environmental] R&D to maximize profits, then the imposition of a constraint that changes the R&D level would tend to lower profits" (23). On the other hand, "(s)atisficing firms may miss opportunities for increased profits simply because they don't look very hard for such opportunities as long as things are going reasonably well. An external shock such as a new environmental constraint can therefore constitute a stimulus to new search, possibly leading to discovery of previously undetected profit opportunities" (23). Again, the dichotomy could equally be applied to understandings of SEM adoption.

Introducing transaction costs and bounded rationality on the neoclassical side complicates matters, as discussed in the last two sections. Now firms are not necessarily seen as choosing a globally best set of techniques and outputs, but rather a set that optimally balances the expected costs and benefits of looking further for improvements. Anything that affects those expected search costs and benefits could stimulate discovery of profit-increasing alternatives. Along the lines of the argument presented earlier, the "anything" would more likely arise from outside the firm; even a decision to expend resources developing new internal capabilities would be seen as having been induced by some external change in the expected payoff structure. While the standard dichotomy's neoclassical predictions remain as potential outcomes, now it is also possible that outcomes associated above with the predictions of evolutionary capabilities theory could be understood within this modified neoclassical/bounded rationality framework as well.

How can the theories' predictions, then, be distinguished in empirically falsifiable ways? While it is impossible to devise clean and simple distinctions, neverthe-

less the logics of the two frameworks differ sufficiently for the nuances of observed behavior to tell us something about the behavior's degree and ease of fit with the alternative approaches. Which perspective provides the better explanation for SEM project adoption will depend upon factors like the following:

Was the initial stimulus more external or internal? Of course, even if the project arose because a manager simply decided to do it, *something* gave her or him the idea, and ultimately information accessed from outside the firm was involved. But was it some proximate change in the firm's environment that upset its prior balancing of expected costs and benefits?

If the firm had previously been aware of the problem or possibility, how hard had managers tried to address it? Was prior non-pursuit of some related project based on a reasonably careful weighing of expected costs and benefits, or simply on satisfaction with an existing way of doing things?

Once induced to examine possible new responses, how far did managers have to look? Put another way, how costly was it to assemble the information required in responding to the problem or possibility?

What kinds of lags were involved? If managers had previously been aware of the requisite information, for how long? If they had not, but if upon investigation the information was quickly and easily available, for how long had it been so?

No one of the above considerations may be sufficient in deciding which theory's predictions provide a better fit for each case. But taken together, they may permit a reasonable classification: one that follows from theory with economy and consistency with its overall logic. In general, the neoclassical/bounded rationality perspective will work better for cases in which the SEM project was stimulated by some external change, and/or the prior state reflected a purposeful choice based on costs and benefits expected from alternative actions, and/or any relevant information that was not previously being utilized would have been very costly to obtain or had not been available very long. On the other hand, the evolutionary capabilities framework will work better for cases in which project adoption followed from an internal change in focus, and/or the prior state evolved as being "good enough," and/or previously-unutilized but relevant information would have easily available over some period of time.

Table 1 summarizes the empirical predictions of the neoclassical and evolutionary capabilities theories, incorporating both the standard dichotomy and the implications of bounded rationality. Its logic is as follows: If hypothetical scenario characteristics would be predicted with reasonable fit and economy by neoclassical theory, they are so classified; if they cannot, but would be predicted with better fit and economy by evolutionary capabilities theory, they are classified that way.

There are four basic kinds of scenarios represented in Table 1. In the upper left, a change in the firm's environment imposes additional costs, leading to project adoption as a loss-minimizing step; this scenario can be easily explained within the standard neoclassical framework.

The scenario in the upper right shows a firm that adopts a profit-reducing project in the absence of any major external change, evidently for non-economic reasons and thus outside the scope of either theory. Impact reduction may be sought strictly in pursuit of social goals. Such situations do occur, and if observed fall outside the

Table 1. Empirical predictions: Neoclassical and evolutionary theories

	Change in expected costs and benefits (information)	Change in focus (how information is processed)
Decrease profitability	**Neoclassical** (loss-minimization)	**Theories NA** (non-economic motivation)
Increase profitability	*Stimulus* – more external	..... more internal
	Prior state – carefully chosen	..... evolved as satisfactory
	Information – costly	.....easily available
	Information – very recent ...	..... previously available
	Neoclassical / bounded rationality	**Evolutionary** .....**capabilities**

focus of this research, which is concerned essentially with how economic opportunities are identified and exploited.[4]

The bottom row portrays a set of scenarios whose boundaries are fuzzy, with a continuum of possible values over the four dimensions used to describe the profit-enhancing project adoption. At the far left is a scenario that fits easily within the standard neoclassical framework: an optimizer, who in the limit moves from one "best available" choice to another made feasible by an externally occurring change in the calculus of expected cost and benefit. Moving slightly to the right increases the importance of bounded rationality in the neoclassically predicted scenario: project adoption involves a profit opportunity that existed previously but only now becomes the optimal choice for the firm. On the far right is a scenario whose neoclassical fit is far less comfortable, but that works well within the evolutionary theory: a satisficer, refocusing managerial attention on a profit opportunity that may have been very close by. In the middle are potentially indeterminate scenarios, which might be consistent with either theoretical perspective: External change might be involved, more critical within the neoclassical framework but neither necessary nor sufficient from the capabilities perspective; the requisite information may have been more or less easily available, with "more" being harder to square with neoclassical theory, because rationality that bounded begins to suggest (within that framework) a decision making breakdown over some prior period of time.

The next section applies the expected empirical scenarios conceptualized within these two theoretical frameworks to a sample of observed cases, and explores the degree of each case's match with the predicted scenarios.

5 A survey of SEM project adoption

A survey designed to test the foregoing theoretical implications was conducted during the spring of 2000. The survey examines the decision making process and environment around companies' adoption of SEM projects. It seeks answers to two, interconnected questions: How is the project expected to contribute to profitability?

[4] It is also possible that an SEM initiative is undertaken in the belief that even though the project itself is not profitable, it will contribute to the firm's long term success. The present study is not designed to explore this potentially important scenario.

And in what scenario did the project arise? As argued above, these questions taken together would be expected to be answered in different ways within capabilities and neoclassical theories of the firm; the survey is designed to get at those differences through the medium of respondents' experiences. Its intent is to try out the lenses provided by the theories in looking at the cases, and to permit reconsideration of the theories in light of this sample.

Twenty regional companies were approached for participation in the survey. All are active members of a regional Pollution Prevention Roundtable, and as such are leaders in SEM within their industries and communities. Survey participation was focused on Roundtable members, rather than a sample of both SEM adopters and non-adopters, because the goal is to distinguish between neoclassical and capabilities approaches to explaining observed SEM opportunities, not between firms that practice and do not practice SEM. Seventeen companies responded. They range from small, locally owned firms to local establishments of multinational companies, and from fewer than one hundred to several thousand employees. All are manufacturers. Table 2 presents some basic descriptive information.

Table 2. Company characteristics (company identifying numbers: see Table 3 and Appendix)

	Number of employees at establishment(s) affected		
Ownership status	0–100	101–500	> 500
Local, multifacility		12	8
Local, single facility	1, 4	11, 15	
Subsidiary of parent company	2	6	9
Local establishments of parent company		3, 5, 13, 14, 16	7, 10, 17

Each company received a one page cover letter and a set of questions covering both sides of a second sheet (available from the author). The packet was addressed to the company's representative to the Roundtable, and the letter motivated its request for participation by reference to prior work done jointly in the Roundtable with the author of this study. The letter described the study as "designed to help us better understand how companies adopt changes that are environmentally and bottom-line friendly." Recipients were asked to "identify *one specific change your company has made within the last five years*, designed to reduce environmental impacts"; to collect information regarding a list of questions about that change; and to agree to meet with researchers to discuss that information. Phone calls followed the mailing, and 17 respondents ended up being interviewed in person. The survey and interview questions can be summarized as follows:

1. What was the SEM project?
2. What specific environmental impact was to be reduced? How and when did you become aware of it?
3. Was the cause of the environmental impact obvious? If not, how did you determine what was causing the impact?
4. How was the organizational change identified for reducing this impact? Was it chosen over other environmentally related changes that were considered for dealing with this impact? If so, why?

5. Did the change require adopting any new or different technologies, materials, or practices? If so, did you invent these yourselves or adapt them from sources outside the company? Had the technologies, materials, or practices been around for awhile, and if so had you previously been aware of them?
6. In considering the change, was its financial impact evaluated regarding upfront expenditures? ongoing operating costs? ongoing cost savings and/or revenue streams?
7. What was the balance of financial, regulatory, and environmental considerations when the change was first proposed? when it was approved for adoption?
8. What were the outcomes of the change (if there had been time to determine these): environmental, financial, market, regulatory, organizational?

The interviewers worked with an expanded survey form, listing additional detail around each of the eight main question areas. Notes taken on this form provided the written record of each session. Each interview lasted about forty five minutes. Survey results for each company are summarized in Table 3, with expanded summaries using Table 3's column-heading categories given in the Appendix.

A wide range of projects was reported, with some types undertaken by more than one company. Three firms (companies 6, 7, and 9) changed from chlorine-based to alkaline parts degreasers, and two (companies 10 and 12) switched to water-based paints with fewer air emissions and hazardous solid wastes. Three companies reconfigured systems to allow inputs or output that formerly had escaped as waste to be captured and reintroduced into the production process, thus decreasing materials usage and landfilling or incineration of solid waste (companies 1, 2, and 3); inputs were also reduced by another firm whose water usage was cut sharply (company 4). Finally, two respondents (companies 8 and 15) chose to report organizational changes *per se*, the creation of ongoing environmental management processes.

One firm began a project for environmental reasons alone (company 5), and not for financial returns, either increased profit or reduced cost; two others (14 and 16) initiated projects for which environmental concerns were an afterthought. The other fourteen sought one or more of the five SEM-expected profitability linkages discussed in Section 4; more than one may apply to a given initiative, since the five are not mutually exclusive. Before analyzing the cases in terms of the theoretical scenarios discussed earlier, it is useful to specify these linkages: In eleven projects, environmental impacts were used as clues to economic waste; of these, five reduced materials usage outright (companies 1-4 and 13), and five (companies 6, 7, 9, 10 and 17) switched to inputs with fewer volatile atmospheric emissions. Two cases saw SEM become a spur to profitable innovation; for company 13 the impetus was external, *via* tightened regulation, and for company 3 the SEM program itself acted as an internal spur. Hidden costs were thought to be reduced in four reports (companies 2, 7, 10, and 11), as expected liability, reporting, and stakeholder relations expenses were seen as lowered; but in no case was an effort made to quantify these savings. Similarly, four firms (2, 4, 8, and 10) believed without tangible evidence that their management systems and practices in general had been improved by the SEM project. Finally, four companies (1, 10, 15, and 17) saw enhanced market position from their SEM initiatives; company 17 began its consideration of the project for stakeholder relations reasons, but decided to go ahead only after realizing that

Table 3. Survey cases: project summaries

Firm	SEM project	Expected profit effect of reducing impact	Project stimulus	Information source and cost
1	Reclaim waste product from customer, reformulate and sell back at a discount	Increase: clue to waste; market opportunity	Customer request	Trade journals; easily available
2	Reduce cutting oil and pkg; waste via reusable containers, used oil filtration	Increase: clue to waste; better management; cut hidden costs	Manager decision; had been participating in P2 roundtable	Word of mouth; vendor; easily available
3	Reclaim and reuse raw material wasted in production; design simple recapture system	Increase: clue to waste; spur to innovation	New manager's decision: renew previously failed effort	Another facility's system; past experience; easily and cheaply available
4	Reduce water use in production, via series of small, simple changes	Increase: clue to waste; better management	Regulatory: worry about major rate hike in future	Internal audit; significant time required
5	Recycle packaging containers of waste product	Decrease: clue to waste? (Economic motive not key)	Employee concerns	Internal audit; industry sources; supplier; easily available
6	Replace chlorine-based with aqueous parts degreasing; new equipment installed	Decrease: clue to waste? (Cost minimization)	Regulatory: reporting change; new technology available	Vendors, consultant audit; significant time required
7	Replace chlorine-based with aqueous parts degreasing	Increase: clue to waste; cut hidden costs	Customer request; firm 7 had been suggesting for some time	industry sources; vendors; easily available
8	Create ongoing environ. committee, change various procedures	Increase: clue to waste; better management; cut hidden costs	New manager decision to address pre-existing compliance problems	Journals; networking; some time required
9	Replace chlorine-based with aqueous parts degreasing; new equipment installed	Decrease: clue to waste? (Cost minimization)	Regulatory: clean air act amendment	Vendors; trade shows and journals; significant time required

Table 3 (continued)

Firm	SEM project	Expected profit effect of reducing impact	Project stimulus	Information source and cost
10	Replace solvent- with water-based paint on products; product quality improved	Increase: market opportunities, better mgt., cut hidden costs	Regulatory: worried about SARA/TRI reporting status	Vendors; easily available
11	Initiate waste dust collection and disposal; equipment and disposal costs	Decrease: cut hidden costs? (Cost minimization)	Regulatory: had been out of compliance	Vendors; easily available
12	Improve water-based paint on products; avoid costlier options; better finish	Decrease, probably; but, market opportunities? (Cost minimization?)	Regulatory: concerned about future compliance	Vendors; easily available
13	Reduced VOC use and emissions by small process change	Increase: clue to waste; spur to innovation	Regulatory: expanded output pushed firm near regulatory limits	Cross functional problem solving; easily available information
14	Plant expansion designed to raise productivity: reduce inputs and waste	Increase, but not by means of environmental management	Demand side pressure for more efficient production	Industry sources, internal team, vendors, state; significant time involved
15	Create ongoing waste committee, identify new practices (some equipment required)	Increase: market opportunities, clue to waste	Management decision: saw image, cost opportunities	Vendors; other firms; internal audit, cross-dept. team; took some time
16	Reschedule compactor pick up to as-needed basis; install automatic guage/fax device	Increase, but not by means of environmental management	New technology became available	Vendor
17	Reduce VOC use and emissions by process change	Increase: clue to waste; market opportunities	Regulatory: public concern about TRI numbers	Joint industry-NGO research effort; adapted by cross-dept. team at plant

an improved product would result. Company 12, whose project was undertaken to minimize the added costs of new regulation, hoped to end up financially ahead due to induced market opportunities not initially anticipated, again due to resulting product quality improvements.

How do all these cases line up with respect to the empirical scenarios predicted by neoclassical and evolutionary capabilities theory? The considerations summarized in Table 1 suggest attention to the decision making process around project adoption, regarding the balance of factors internal and external to the firm; the nature of the information utilized; and how managers acted upon that information. In terms of the stimuli that triggered new SEM practices, one or more outside influences were involved for many-regulatory, pricing, demand, or technological. Here especially proximate stimuli will be considered; external conditions change continually, but we are most interested in those that could be seen as causal in determining why a particular change was undertaken at a particular time. Obtaining the information used in project design sometimes required considerable time and effort, but other times did not; in some cases, the requisite knowledge had only recently arisen or become available to managers, while in others it had been around for some time.

Table 4 superimposes the survey cases on the four basic scenarios proposed initially in Table 1. It is constructed by asking first whether the circumstances of each case fit well with a scenario predicted by neoclassical theory. If so, the case is located in the upper left cell or at the far left edge of the lower left cell. If not, and a scenario predicted by evolutionary capabilities theory seems clearly to provide a good fit, the case is placed at the far right of the lower right cell. If the case is not a clear neoclassical fit but could reasonably be explained within either framework, it is located somewhere along the continuum between the left and right edges of the bottom row; thus, the boundary between the lower left neoclassical scenario and the lower right capabilities one is shown as porous. In interpreting Table 4, the reader may wish to refer to Table 3's schematic case summaries and/or the fuller ones contained in the Appendix. The four scenarios are as follows:[5]

1. A loss-minimizing change made in response to an external shift. Upper left: This scenario holds for companies 6, 9, 11 and 12, which responded to regulatory changes with SEM-based cost minimizing adaptations. A neoclassical story works well with these cases, as an exogenous shift stimulated behavioral change intended to minimize the resulting erosion of profits. It is true that when the survey interview was conducted, the representative of firm 12 reported, managers there had begun to suspect that a market repositioning unexpectedly made possible by the SEM project might yield additional revenues more than offsetting the project's added costs; but at the time that had yet to be determined.

2. A profit-reducing initiative undertaken for non-economic reasons. Upper right: Company number 5 began its environmental management project in order to accommodate employees' and community preferences for cleaner production. Although

[5] The two firms (14 and 16) that undertook projects for which, in the judgment of the researchers, environmental management considerations were not central have been excluded from Table 4.

Table 4. Survey cases (company numbers): neoclassical and evolutionary capabilities scenarios

	Change in expected costs and benefits (information)	Change in focus (how information is processed)
Decrease profitability	**Neoclassical** *Regulatory shift*: 6, 9, 11, 12	**Theories NA** *Non-economic goal*: 5
Increase profitability	*Customer/public pressure shift*: 7 . . . . . 17 . . . . . 1 . . . . . . *Internal problem solving*: . . . . . 3 **Neoclassical / bounded rationality**	*Regulatory stimulus to refocusing*: . . . . . 4, 10, 13 . . . . . . *No proximate external stimulus*: 8 . . . . . 2, 15 **Evolutionary capabilities**

SEM capabilities were employed, the effort falls outside the scope of either theory, which seek to explain profit-seeking activity.

3. Discovery or arrival of new information, stimulating adoption of a project that would not earlier have been profit-enhancing. There are two kinds of scenario in this lower left cell of Table 4, both of which can be described using neoclassical theory.

An external shift: These three cases (7, 17, and 1) move along the continuum (pictured in the bottom row of Table 4) between the predictions of neoclassical theory and the capabilities framework. Company 7 shows a clear and comfortable neoclassical fit: Its sales account managers for some time had been urging a major customer to accept product embodying a well known, impact-reducing technology replacing chlorine-based with aqueous parts degreasing; the customer finally agreed. [6] Company 17 adopted a new technology to reduce its Toxic Release Inventory (TRI) figures, a move explored for public relations purposes but chosen when the technique unexpectedly created revenue-increasing product improvements. A long time passed between the external stimulus (the TRI was established in 1986) and project adoption (1995); but the new technology required time and a broad partnership effort to develop, and the neoclassical/bounded rationality fit is still reasonable. Company 1 creates the greatest stretch for the neoclassical scenario. A customer request stimulated the firm to adopt a product waste-capturing technology; the managers were already well aware of the technique, it was easily and cheaply implemented, and additional customers for the new process were quickly found as well. But certainly the initial request increased the expected benefits of making the change, and hence the case categorization in Table 4.

Internal problem solving: Company 3 represents an especially fuzzy case within scenario 4, and has been placed just on the neoclassical side of the midpoint in Table 4's bottom row. A manager tackled and succeeded in solving a problem of potentially saleable product wasted during production, which several years earlier a previous manager had tried but failed to fix. The current manager did utilize in-

[6] The customer had earlier insisted on what was industry-wide standard practice. Thus while this individual scenario works well in neoclassical terms, it also illustrates the very slow relaxation of an industry lock-in of inefficient technology, as described by David (1985) in questioning standard theoretical explanations of observed technique.

formation from the earlier attempt and from a successful example at another plant within the company, as would be expected in a bounded rationality process, and hence the case's placement in Table 4. But all of this information was available to his predecessor after the first trial; what the new employee provided was increased willingness to revisit the problem, a focus shift as might be suggested in an evolutionary capabilities process.

4. A profit-increasing SEM opportunity discovered in very close "proximity" and/or without any proximate external shift . These cases are better explained by evolutionary capabilities theory, although they too vary along the continuum represented in the bottom row of Table 4:

Companies 2 and 15 initiated profitable SEM activities simply because current managers decided to do it; ultimately the information that stimulated these decisions came from outside the firm, but there was no proximate trigger in either case. (Case 2 is discussed below in some detail.) Firm 8 differs from these two only in that the decision was made by a new manager. Did this entail what might through a neoclassical lens be seen as the arrival of new information? I have located this case farther toward the neoclassical/bounded rationality cell, but still on the capabilities theory side, because the previous environmental manager was equally aware of the ongoing regulatory compliance problems that stimulated his replacement to act; the new employee brought a change in focus, but no new information about expected costs and benefits.

Companies 4, 10, and 13 represent a different subcategory within scenario 4. They were stimulated by regulatory pressures to locate profit opportunities that had existed all along in very close proximity, in that managers quickly and inexpensively used already available information to make changes that increased profitability. It is true that the pressure raised the expected cost of doing nothing, tantamount to increasing the expected benefits of searching for a new method-as predicted in the neoclassical/bounded rationality framework. But finding that new method so close at hand would suggest (within that framework) at least that search costs had been substantially over-estimated, which stretches the optimal choice logic of the model. Strategic re-focusing, as predicted in the evolutionary capabilities perspective, provides a simpler and more comfortable fit.

As noted, Table 4's cells were populated by asking first whether the empirical implications of neoclassical theory work reasonably well for each survey case. In several instances they do not seem to. The apparent tension between the precepts of SEM and of neoclassical optimizing, even with bounded rationality taken into account, is given some credence by this sample of SEM projects. The six or seven cases that are hard to square with the predictions of neoclassical theory fit better with evolutionary capabilities theory's emphases on focus, routines, horizontal information flows, and organizational learning. As managers and other employees turned their attention to environmental impacts as clues to economic waste, they created or adapted innovative techniques or products; they reduced previously hidden environmental costs; they seized new market opportunities. Some organizations were able more quickly and easily to implement projects based on existing environmental management competencies. Others undertook strategic refocusing

in a broader sense, by investing (sometimes significant) resources to create new competitive capabilities.

It was noted in an earlier section that capabilities theory can help explain the transition from pollution control to pollution prevention. Company 2 provides an example. The operations manager in this small metal-working firm became aware of SEM by attending a forum at a local college; he subsequently joined the Pollution Prevention Roundtable, at whose meetings he heard best practice reports from peers and began to look more carefully at the causes and costs of pollution in his own shop. His efforts to control cutting oil waste (and hence purchase and cleanup costs) led over a two year period to a plan for an interconnected set of process changes in oil purchasing, storage, removal from metal turnings, filtration, and re-use. Evolution of the firm's SEM capabilities allowed it to reduce pollution at the source, with a significant boost to profitability as the ensuing cost savings quickly paid back the time and capital investments required by the process changes.

Table 4 displays mixed results with respect to the Porter hypothesis. Companies 6, 9, 11, and 12 chose SEM projects to minimize the costs of new regulation, as Porter's critics have suggested (Walley and Whitehead, 1994; Palmer et al., 1995). On the other hand, cases 4, 10, and 13 seem consistent with the hypothesized outcomes. Firms 4 and 13 report SEM projects that increased profits after being induced by regulation, but could have done so given any focus-changing stimulus: as predicted, SEM spurred by regulatory pressure uncovered profit opportunities that had been in close proximity all along, given the information easily available to these firms. For company 4 the change represented diffusion of existing technologies; number 13's entailed a small but profitable process innovation. Firm 10's project also seems consistent with the Porter hypothesis; although substantial upfront capital costs were involved, the resulting change (diffusion of existing technology) increased profitability by improving product quality. Even company 12, after beginning its project to comply with new regulation in the least costly way, found that improved and lower-impact product characteristics opened new market opportunities that might, in time, more than offset the added costs. Thus even during the relatively short time frame covered by the survey questions, close to half of the firms affected by tighter regulation experienced the kinds of induced technical change and cost offsets suggested by the Porter hypothesis.

6 Conclusion

These survey results provide evidence for the existence of a significant body of corporate environmental management practice that fits well within a capabilities based theory of the firm. The production and sales routines incorporated in many respondents' pre-project practices embodied traditional economy-environment notions, within whose context it made little sense to seek further efficiencies. With heightened regulatory pressures or intra-firm re-focusing, managers in these companies were able to harness cross functional information sharing to follow the clues offered by environmental impacts, regarding sources of economic waste and/or market demand. Sometimes this led to innovation, as truly unique solutions were created, or more often to adoption or adaptation of others' existing approaches. In

either case, new routines and capabilities were created by purposeful investment of resources and organizational learning. In the process, sometimes, firms became better-managed: they learned how to learn.

By providing a framework for understanding the processes and potential gains of environmental management, an evolutionary theory of organizational capabilities can contribute to important debates over public and corporate policy. Both the Porter hypothesis and SEM are based on the idea that firms are able to respond to stimulus (external in the former, internal in the latter) by discovering better ways of doing things, and that is what capabilities theory explains. This perspective offers a systematic rubric within which to address neoclassically oriented criticisms of the Porter notion and, the focus in the present study, SEM. Practitioners of SEM, while including top executives of some well known global corporations, often labor at the middle management levels of companies whose leaders are skeptical of the value of the approach. Given the increasing prominence of SEM worldwide and its claim to relax the tradeoffs between economy and environment, it is important to uncover and critique the theoretical underpinnings of the skeptics' view. Resistance to SEM is often related to (among other things) the fact that it is difficult to square with neoclassical assumptions and conclusions about how firms operate. Here neoclassical theory takes its familiar stance: what *is* in the marketplace most likely *is best*; and if it is not socially best in this case, then private firms' loss in correcting market outcomes must be recognized.

Certainly the survey results reported here show a substantial number of cases whose dynamics are not inconsistent with this neoclassical idea. But these results also document a considerable body of SEM practice that contradicts the gloomy predictions of neoclassical theory. The capabilities framework helps by suggesting that this gloom is at least in significant respects unjustified: it is theoretically sound and reasonable on practical grounds for firms to seek competitive strategies based on reconciling economic and environmental goals.

Appendix: Summary survey responses

Company #1*:* independent local firm; about 50 employees.

- SEM project: Worked with a customer to reclaim waste product (used as input to customer's production process), and reconstitute it into new product. Customer ships out 110 less gallons of hazardous waste a week; raw materials and energy usage decreased.
- *Expected profit effect of reducing impact*: Depletion of natural resources from raw materials in making product, the hauling and incineration of hazardous waste. No significant capital costs for either party. No new costs in transport (waste to be reconstituted is shipped back to producer on formerly empty delivery truck return trips). Customer saved $75,000 in 1995 with the change. Supplier sells the reconstituted product at a higher profit margin and markets this service now to other customers.
- *Project stimulus:* Customer request; had heard about the change within the industry. Primary concern for customer and supplier was financial. Customer was not out of compliance.

- *Information source & cost:* The manager of regulatory affairs learned of the process from industry and pollution prevention magazines. The manager modified the existing technology in the customer's production process; no significant new technology was needed. The firm's manager of regulatory affairs, R&D, lab manager, technical director, and the customer's purchasing manager were involved.

Company #2: 50-employee subsidiary of international company.

- *SEM project:* A chip spinner to clean oil from turnings, reusable high-quantity oil containers, & oil filtration device: increased oil recycling, reduced waste oil and water, 55-gallon drums no longer put into landfills, and improved in-shop waste containment and management.
- *Expected profit effect of reducing impact*: Upfront expenditures were $16,800 for the chip spinner and filter; ongoing operating costs for the spinner. Savings more than recaptured cost: reduction in 55 gallon drums discarded, oil used & wasted, mop water used; oil bought in bulk size.
- *Project stimulus:* The manager had been working with a local pollution prevention roundtable, and decided to tackle some problems of which he had been aware for some time.
- *Information source & cost:* Most ideas from outside; employee had heard of the chip spinner, and manager talked to the oil supplier. They adapted the filter process themselves, but the spinner and filter were widely known in the industry. Plant manager was involved but no formal meetings were held.

Company #3: 400 employees; facility of large, national independent firm.

- *SEM project:* Collected material debris with a dust collector and reintroduced the debris as raw materials in the manufacturing process. Installed diverter gate constructed out of sheet metal. It needed a small amount of materials, but the technology was basic duct work. Reduced debris landfilled (196 tons less in 1999 than in 1996), energy in extracting & processing the raw materials, depletion of natural resources.
- *Expected profit effect of reducing impact*: The cost of the diverter gate was $1,500 paid to a sheet metal worker; no operating costs. There are ongoing cost savings in waste disposal (about $10,000 annually), energy use and raw materials.
- *Project stimulus:* Environmental manager identified an opportunity to re-initiate a project that had been tried previously without success.
- *Information source & cost:* The environmental manager had heard of the previous attempt and read that the same type of impact reduction was being done in another of the company's plants. Brainstorming with the production manager was involved in adapting the process to their plant.

Company #4: small independent firm; 70 employees.

- *SEM project:* New equipment & rinsing techniques, and employee education (turning off water and learning new rinsing techniques), to reduce water usage. Reduced water consumption from 14.3 million gallons in 1992 to 5.9 million gallons in 1999.
- *Expected profit effect of reducing impact*: Upfront costs were only $200, with very little labor cost; no new operating costs. Ongoing savings in water. A major

capital expenditure was avoided: able to stay with the existing in house water treatment system and reduce its maintenance costs (the less water pumped through it the less stress on it). Total savings over 8 years have been $75,433. Lasting changes in the organization have been significant. Employees better about watching water usage. Due to this success the water team turned into an environmental committee; meets regularly, has initiated other profitable activities.

- *Project stimulus:* Regulatory: The city water authority planned to increase water prices for conservation reasons. In addition, their water treatment system was having trouble keeping up with volume, and at times the company was out of compliance.
- *Information source & cost:* Bills and records were looked at. Then a water team (administrative V.P., purchasing manager, technicians, line supervisors, and hourly employees) examined specific points where water was being used inefficiently. Most changes were common plumbing fixes, such as turn off valves and flow constrictors. Cascade rinsing was a new technique to the company but not to the industry. All technologies known prior to the initiation.

Company #5: medium-size firm with two facilities; about 430 employees at this, the major facility.

- *SEM project:* Recycling the containers of product throw-aways and test samples: steel, aluminum, cardboard, PETE, other plastic. Installed a new capping system, along with bins for the recycled containers and material handling equipment. Reduced waste put into landfills, with the ability to leech into groundwater; and energy needed to make containers from virgin materials.
- *Expected profit effect of reducing impact*: Not financially driven. Employee satisfaction was increased greatly, and there is no way to quantify that. There is no data on the financial outcome of this project.
- *Project stimulus:* Most importantly, employees' attitudes and opinions about the environment were taken into consideration when making the waste minimizing changes.
- *Information source & cost:* The plant engineer, plant supervisors, and hourly employees were involved. The new capping system was new technology, and it took awhile to work on this with the supplier.

Company #6: subsidiary of a parent corporation; about 230 employees.

- *SEM project:* The company went from using hazardous chlorine-based degreasing systems to aqueous degreasing. Reduced TCEs (trichloroethylene), which had been recycled or generated a sludge landfilled as hazardous waste, and CFCs (chlorofluorocarbons). Reduced TCE to 200lbs/month. Dropped into the small quantity generator category, reducing record keeping and waste tracking and enhancing image with European Community customers. Have increased safety.
- *Expected profit effect of reducing impact:* Costly, but most effective way of meeting goals. New tanks were $1500, four new degreasing machines ranged from $10,000-$2,000. The aqueous solvent costs the same as the TCE. Eliminated disposal and recycling charges for TCE. With the reduction made in VOCs they were able to buy a smaller boiler for the plant heating system.

- *Project stimulus:* The main driver was regulation; they wanted to reduce their VOCs to get a lower category air permit. The focus wasn't on financial aspects.
- *Information source & cost:* Many people were involved: the environment manager, supervisors, demonstrators, vendors, and employees. In particular, vendors and demonstrators helped to figure out the most cost-effective solution. The company had an air emissions inventory done at the plant. New machines were brought in and tried for a number of days. Some of this technology was fairly new, within the last couple of years. Some information was gotten from trade magazines.

Company #7: large independent multinational corporation, mostly domestic; several thousand employees.

- *SEM project:* The company changed from using perchloroethylene, a chlorinated chemical that had to be shipped as hazardous waste, to alkaline degreasing solvent. They simply increased the strength and duration of the alkaline bath technology already used in the facilities. Eliminated perc entirely by 1995.
- *Expected profit effect of reducing impact:* Cost-reducing. No upfront costs in strengthening the baths. Don't have to purchase perc, haul it away, and dispose of it anymore. Don't use much more alkaline than before and this isn't treated as a hazardous waste. The change is associated with moving one of the facilities into a lower regulatory category.
- *Project stimulus:* A combination of customer preference and finance. Major buyer dropped opposition to the switch, as technical standards in its own industry changed. There is much potential liability and possibility for fines with perc; knew they would save money in making the change as well.
- *Information source & cost:* There were other options beside alkaline degreasers, but alkaline was already used in the 2^{nd} step of the cleaning process. So, they used the technology they had. The corporate environmental manager, product/process engineers, and facility environmental managers were involved in the change. Some companies were doing this in the industry. Vendors and chemical suppliers gave advice on exact steps.

Company #8: independent company with about 1300 employees.

- *SEM project:* Organizational: initiated an environmental committee 3 years ago. The committee was set up to examine environmental impacts prior to beginning all new product lines, and before processes are changed; its members change depending on the process to be examined. A typical cross-functional committee includes: line supervisors, R&D, management, process engineers, environmental engineers.
- *Expected profit effect of reducing impact:* Increase profitability. No upfront costs involved, but management was restructured which is a cost. There are time costs involved in the meetings. Then the process changes may involve capital. Cost-benefit analyses are always done when examining the process to be altered or initiated.
- *Project stimulus:* The hiring of a new environmental manager, who noticed the company was dealing with things "after the fact," and was-as his predecessor

had been aware-often out of compliance. There were fines, and production was stopped to fix some of the problems
- *Information source & cost:* The manager read about environmental management in magazines, trade journals, and the internet, and attended workshops held by the state environmental agency.

Company #9: subsidiary of a larger corporation; about 1000 employees.
- *SEM project:* Switched from using trichloroethylene to an aqueous amine degreaser. New machines were needed along with the new amine cleaning solvent, plus a new filtration and water treatment system to recycle the amine solvent. Reductions of 10,000 lbs. of TCE hazardous sludge and 16,000 lbs of virgin TCE has resulted.
- *Expected profit effect of reducing impact:* Minimize the costs of meeting regulations. 6 new machines ranging from $100,000–$200,000. Around $50,000 a year in ongoing cost savings (the new cleaner is cheaper than TCE including disposal costs). The ultrafiltration membrane system was $80,000; an NPV was assessed ahead of time, and it paid for itself in 8 months. The new machines are a little more energy intensive. The old machines were working fine.
- *Project stimulus:* The company wanted to avoid problems with a Title 5 permit. There were new standards coming out for VOCs. In addition, OSHA lowered the exposure limits of VOCS. Without the change it would have cost between $1/2million to $1million dollars for stack control systems.
- *Information source & cost:* Most of the work was done by the environmental engineer, who worked with vendors in identifying a new solvent that could be used. Several machines were brought in to see how they performed with the company's product, and employees gave feedback. Options were also explored through cleaning/surfacing shows, and magazines. The new solvent had been well known in the business for 20 years. The ultrafiltration devices were invented in the last 5 years.

Company #10: a large independent multinational; about 5,000 employees.
- *SEM project:* Went from using solvent based paint (which gave off VOCs and contained xylene) to water based paint on their products. New accelerated heating systems were needed on each of the paint booths. The product had to be cleaned for a longer time before applying the new paint. Have reduced 25% of the hazardous waste associated with paint.
- *Expected profit effect of reducing impact:* Increased. The exact financial outcomes haven't been assessed but the interviewee really feels the company has seen net benefits through marketing to the customers. 18 new accelerated heating systems at $40,000 each. Increased time to clean the parts. New paint costs more but they can use less. Reduced costs in disposal and liability. Safety has been increased; the project's success has sparked other environmental teams and has increased awareness throughout the company.
- *Project stimulus:* Not out of compliance, but looking to get ahead of the game. Saw this as a competitive advantage.
- *Information source & cost:* The environmental engineer set up a cross-functional team: engineering, sales, custom training, and manufacturing. Most importantly,

vendors were used to identify possible changes the company could make. New paint had been around for 8 years. Knowledge was also found in magazines readily.

Company #11: independent single-facility firm of about 200 employees.

- *SEM project:* A dust collection device with hoods was installed in a mixing room. Prior to this the dust was being sucked out of the room to the outside. The hoods and duct work that needed to be attached to the dust collector were made in-house. Eliminated 16,000 tons of dust emissions per year.
- *Expected profit effect of reducing impact:* Minimize compliance costs. The dust collector and hoods were $110,000. There are operating costs involved with the collector. The company has to pay for disposal now in the form of residual waste that needs to be landfilled.
- *Project stimulus:* Newly hired environmental manager. Prior to this, the company had been out of compliance for some time.
- *Information source & cost:* An outside source did some testing, in particular for VOCs. The environmental manager, president of company, and facility's engineer were involved in the change. The dust collector was not new technology.

Company #12: a small independent firm of about 260 employees, with two facilities.

- *SEM project:* Improving a water-based paint used on their product, reducing hazardous air pollutants (VOCs). Can use the new paint in existing machines. Decreased a specific HAP by 24,000 lbs/year.
- *Expected profit effect of reducing impact:* Minimize costs of future compliance, although unanticipated project-related market opportunities have arisen since its initiation. Saw 3 options: wait for new standards and possibly have to put $1 million control systems on stacks, go to capital-intensive and space-intensive powder coating, or improve current water-based paints. No upfront costs with this option, except moving a paint line during 5 weekends of labor. The new paint costs about $2 more a gallon, but is harder, glossier, and more durable. Will market these aspects of the new paint. The company doesn't know how the net financial aspects of the change will pan out.
- *Project stimulus:* Anticipated regulatory tightening (Clean Air Act).
- *Information source & cost:* The environmental manager, engineering supervisor, plant manager, paint vendor, quality control team, paint supervisor, and employees were involved in making this change. There were meetings and a number of paints went through a test period. They got most of the information from their paint vendors.

Company #13: an establishment of a large corporation; several hundred employees.

- *SEM project:* Slightly increased temperature in the manufacturing process to decrease a specific ether (a VOC) used; no new equipment or materials were needed. Now using 50% less of this VOC.
- *Expected profit effect of reducing impact:* Increase profitability. Considered two possible solutions. Go on emitting at the rate they were and eventually have

to put in control systems ($1.4 million), or look at the process to decrease the VOCs. With the latter, no upfront costs were involved; although the energy cost of increasing the temperature is $20,000/year, they save $250,000 in raw materials yearly.

- *Project stimulus:* Were emitting VOCs nearing regulatory limits as production was increasing.
- *Information source & cost:* A cross-functional team of process operators, engineers, and the environmental manager brainstormed. The team thought of this solution by themselves; no information was gotten from other sources.

Company #14: large firm with 12 manufacturing facilities; about 300 employees at the facility visited.

- *(SEM) project:* An extension was put on a manufacturing plant and equipped with computerized and robotic processes. The main focus was increasing productivity, not environmental impact reduction. But in putting in this extension the company knew it could reduce waste, VOCs, and HAPs.
- *Expected profit effect of reducing impact:* Not applicable.
- *Project stimulus:* The driver behind this was financial, specifically to satisfy customer demand.
- *Information source & cost:* Not applicable.

Company #15: an independent corporation with about 400 employees.

- *SEM project:* Set up a waste committee and worked to reduce its waste being put into a landfill. Many new practices had to be initiated, such as recycling. New materials were needed as well, in the form of bins used for recycling, a bailer, a shredder, and a new parts machine. 7.2 tons less waste was sent out the 1^{st} year of the program. Has set up an awards program and keeps records to show how employees have contributed.
- *Expected profit effect of reducing impact:* Increase, via reduced costs of waste and improved market position with customers. A few cost examples: waste minimization led to $9862 landfill saving in 1 year, closer inspection led to $1870 saved on good parts thrown away, $7830 a year via cardboard recycling, $2966 savings in reduced hazardous waste disposal. (Upfront equipment costs were less than $5000, and the projects involved time.)
- The company became aware of these impacts through legislation and because recycling was being highly publicized.
- *Project stimulus:* There was slight regulatory pressure in the form of residual waste allowances but the main driver was financial. The company felt their customers would be impressed with environmentally responsible performance.
- *Information source & cost:* Each department tracked all waste streams leaving their area. Then a waste committee was set up to talk about the different streams and courses of action: one person from every department, the CEO, the EHS director, purchasing, maintenance, shipping, and hourly employees. Help from vendors and other companies. All the new equipment purchased had been in the industry for some time.

Company #16: an independent manufacturer, with several plants (about 1500 employees) internationally.

- *(SEM) project:* Cut by half the frequency of solid waste hauling, by moving to a pick-up-when-full system for the compactor. Formerly, the hauler came twice weekly for pick up; each time there would be 2-4 tons, although the compactor can hold 8 tons.
- *Expected profit effect of reducing impact:* Though energy costs and air pollution from operation of the waste hauler's trucks are reduced, the impact reduction was a minor by-product of the decision.
- *Project stimulus:* Strictly a financial decision.
- *Information source & cost:* Not applicable.

Company #17: independent corporation with about 50 plants worldwide; this one has 800 workers.

- *SEM project:* Replacing chlorine with hydrogen peroxide bleaching in one of the production stages. New storage tanks, piping, process controls, and safety training were required. Resulted in an annual reduction of 100,000–120,000 pounds of chloroform released into the atmosphere.
- *Expected profit effect of reducing impact:* Increase via cost reductions and, especially, improved market position and sales. Upfront costs of about $400,000 at this facility; the chlorine input and the hydrogen peroxide cost about the same, so there were no ongoing direct cost differentials. But the new process creates a more stable intermediate-stage material, resulting in less wastage and considerable indirect cost savings. The new process also resulted in a better product with a longer shelf life. Revenues increased as customers became convinced of this. A payback period of two years was calculated based on the cost and revenue factors.
- *Project stimulus:* The main driver was reducing Toxic Release Inventory emissions, i.e., improved public perception of the company's operations. Project timing was affected by the realization that a better product was actually achieved.
- *Information source & cost:* NCASI, the National Council for Air & Stream Improvement, worked with the industry on the problem. At the plant, a cross functional group looked at it: top management, R&D, line managers, engineering, and environmental. The environmental department conducted a set of tests.

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