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Industrial Ecology and Competitiveness

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Strategic Implications for the Firm

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Summary

In the emerging field of industrial ecology one of the unsettled questions is the degree to which design for the environment, closing energy and materials loops, and other industrial ecology concepts apply at the firm level. In this article we examine this issue with a particular focus on whether industrial ecology can guide company strategy and efforts to enhance competitiveness.

We conclude that industrial ecology thinking will often be useful for firms seeking to improve their resource productivity and thus their competitiveness. The systems perspective that industrial ecology promotes can help companies find ways to add value or reduce costs both within their own production processes and up and down the supply chain. But industrial ecology cannot always be counted upon to yield competitive advantage at the firm level. In some cases, the cost of closing loops will exceed the benefits. In other cases, regulatory requirements do not fully internalize environmental costs, and thus polluting firms may gain temporary or permanent cost advantages relative to companies that attempt to eliminate all emissions. Finally, because industrial ecology focuses attention on materials and energy flows, it may not optimize other variables that contribute to competitiveness within the corporate setting.

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Introduction

Industrial ecology offers an analytic tool that can be applied in various ways and at various levels of economic aggregation.[1] Because the field is still emerging, considerable debate exists over industrial ecology's use and value in different contexts. In this article, we explore one dimension of industrial ecology: its potential application as a tool for shaping firm strategy and competitiveness. We examine, in particular, the connections between industrial ecology and current work in the fields of competitive strategy and international competitiveness. We observe that industrial ecology can spur a certain type of corporate thinking that, when screened through the lens of *resource productivity*, may lead to innovations that improve efficiency, lower costs, and raise the value created by a production process. Industrial ecology can thus serve as a tool for sharpening firm competitiveness. We note, however, that although industrial ecology has potential in the realm of competitive strategy as a "discovery" tool, it has limitations as a broader firm-level guide for strategy generally.

Design for the environment (DfE), materials cycling, and an emphasis on closed-loop production processes will yield competitive advantages in some circumstances. But in other cases, these approaches will not enhance a firm's competitive position. Notably, closing some loops may add costs that exceed the benefits to be obtained, especially if the regulatory system within which a company operates does not fully internalize the costs of air or water pollution or waste disposal. In addition, attention to energy and materials flows can distract from the optimization of other scarce resources such as the analytic attention of managers.

Firm-Level Industrial Ecology

Managing at the firm level through an industrial ecology lens offers both opportunities to advance competitiveness and potential risks. In the sections that follow, we identify and analyze the potential benefits and then review the limits of industrial ecology as a corporate strategy tool. In doing so, we find, in many circumstances and in many respects, a fundamental alignment between good environmental performance and recent innovation-driven views of what produces competitive advantage.

Industrial Ecology as a Guide to Resource Productivity

In some respects, recent work in industrial ecology—with its emphasis on how effectively various critical resources are employed in a production process—is building on thinking that emerged in the late 1980s and early 1990s on "environment and competitiveness" (Porter 1990; Porter 1991; Esty 1994).While traditional economic thinking argues that competitive positions are built on low-cost inputs, recent work on corporate competitiveness focuses on the dynamic nature of business and the importance of innovation (Porter 1990). Today's competitive advantage often derives from finding unexpected ways to lower the cost of producing goods or identifying ways to increase a product's value—either directly or indirectly. Enhanced *resource productivity* is thus what makes companies truly competitive (Porter and van der Linde 1995a, 106).

Resource productivity can be defined as:

$$\text{resource productivity of input } x = f\,(\text{value added by } x - \text{the direct costs of } x - \text{the indirect costs of } x + \text{the indirect opportunities for value added from } x).$$

In this equation, the *direct* value added and costs are the parts of the production process to which firms currently pay attention. The value added by a resource to the final product of the firm is obviously central to its productivity. As a product becomes more useful and thus worth more to customers, its value increases. Hence companies recognize the importance of trying to find ways to improve the quality, features, or functionality of their products. Direct costs—labor and material inputs—are also traditional parts of most companies' accounting calculus. Companies understand that to the extent they can produce their products with fewer or cheaper inputs, they will improve resource productivity, lower costs, and increase profits.

Some aspects of industrial ecology address opportunities to improve environmental performance and simultaneously to increase the value of a product or to lower direct costs.[2] For example, producers, made more attentive by industrial ecology thinking and life-cycle analysis to waste disposal problems their customers face from the products they have sold, may make changes in a product's design to facilitate recycling or reuse. Such DfE strategies can lower the customers' costs and therefore enhance the product's value. Likewise, a manufacturer who adopts a waste minimization strategy may find he can recapture and reuse raw materials and thus purchase fewer inputs, thereby cutting his direct costs of production.

In addition, many *indirect* or hidden opportunities exist to lower costs or to improve the value of a product. In general, these opportunities arise beyond the scope of a firm's traditional product definition, management vision, and accounting procedures. Below, we separate out three critical places to look for hidden resource productivity gains: (1) within the firm; (2) within the chain of production (involving suppliers or customers); and (3) beyond the chain of production. In each area of opportunity, industrial ecology may be helpful as a discovery tool, broadening the perspective of corporate decision makers, encouraging innovation, and facilitating the reconfiguration of product definition, design, production, delivery, and disposal in ways that can be both profitable and environmentally beneficial.

No doubt skeptics will ask why, if these opportunities for improved competitiveness are so readily available, companies have not already moved to take advantage of them. There are several answers. First, some companies *are* finding these resource-saving opportunities inside and outside their firms that are bringing down costs and improving efficiency. Second, corporate managers have limited time and capacity to focus, and many are just now beginning to appreciate the depth of the opportunities presented by paying attention to resource flows. Finally, to obtain resource productivity gains managers must comprehensively reexamine their operations and think about their firms' activities in new ways, and not everyone has the ability to make the requisite shift in thinking.

Within the Firm

Many ways are available to improve resource productivity by identifying and eliminating waste and thereby lowering the costs of production. Even before the advent of industrial ecology, companies were pursuing these opportunities under the rubric of "pollution prevention" (Dorfman et al. 1992). By fostering a fusion of thinking from the physical sciences about the conservation of mass and energy with the teachings of economics about efficiency, industrial ecology can go even further in helping firms obtain maximum returns from a given set of inputs—that is, to optimize resource productivity. Moreover, by encouraging systems thinking—including attention to a company's materials balance, the possibility of closed-looped systems, and design for the environment opportunities—an industrial ecology perspective can encourage companies to focus on the multiple dimensions of resource productivity that must be considered to optimize competitiveness. Attention to a company's materials balance, the possibility of closed-looped systems, and DfE opportunities can add to the value of a product or reduce the cost of production.

Dow Chemical, for example, redesigned its process for scrubbing the hydrochloric acid used to make chlorinated organic compounds. The refined procedures allowed Dow to eliminate the need for certain wastewater evaporation ponds, to recapture part of the former waste stream for reuse as inputs in other production processes, to reduce its caustic waste by 6,000 tons per year, and to cut its acid waste by 80 tons per year. With an investment of $250,000 to implement the new process, Dow obtained $2.4 million in annual savings on inputs and lower waste disposal costs—cutting both direct and indirect production expenses (Dorfman et al. 1992, 150).

Similarly, companies that have attended to their energy flows—for example, by redesigning their office and factory lighting as part of the U.S. Environmental Protection Agency's (USEPA) Green Lights program—have achieved significant reductions in their electric bills and thus their production costs (Porter and van der Linde 1995a, 99). Although such operating expenditures as lighting are allocated as a cost in production, they are often not considered to be within the management domain of those responsible for a particular production process. Indeed, the key to the success of the USEPA Green Lights program was its emphasis on aggregating lightbulb changes and getting companies to shift responsibility for managing this "resource" from janitors with little incentive to make cost-savings investments in new lightbulb optimization strategies to senior managers who do have such incentives.

Industrial ecology thinking promises broadly to spur attention to opportunities for cost savings that would otherwise go unnoticed. Many companies have undertaken pollution prevention programs with similar cost reduction goals in mind. 3M attributes more than $700 million in cost savings to its Pollution Prevention Pays program (Kelly 1994). A number of other companies have reported similar results (Miller 1996; Hart and Ahuja 1996, Regan 1993). A somewhat broader industrial ecology focus might well yield even larger resource efficiency gains.

In other cases, the industrial ecology analytic framework has sparked creativity and innovation that has led to unanticipated benefits that go beyond waste minimization. Hitachi, for instance, adopted a DfE strategy in its washing machine division to facilitate recycling of old washing machines. In redesigning its product to make disassembly easier, the company developed a process by which its washing machines could be made with just six screws. Not only did this new design facilitate disassembly and waste disposal at the end of the washing machine's life, but the six-screw structure cut manufacturing time by 33% and significantly reduced the number of parts that needed to be kept in inventory, tracked, and acquired. Hitachi also discovered that the six-screw washer required less service, so that the customer got higher reliability and lower repair bills. Hitachi's efforts resulted not only in an environmentally preferable washing machine but a higher-value product with improved customer satisfaction, lower production costs, and reduced indirect costs of disposal (JACO 1996). In this case, the Hitachi commitment to thinking in industrial ecology terms produced a multidimensional increase in resource productivity that made the company's product much more competitive.

Dutch flower producers, under pressure to reduce the use of fertilizers and pesticides that pollute groundwater, achieved similar unanticipated benefits from a commitment to rethinking their production process from a DfE perspective. They developed a closed-loop system for growing flowers in water and rock wool that offers significant enhancements in resource productivity (Porter and van der Linde 1995b, 130). The growers found that the closed-loop growing method lowered the risk of disease, reduced the need for pesticides and fertilizers (which could be recirculated in the water), and narrowed the variations in growing conditions which improved product consistency and quality. Because the flowers in the closed-loop system are cultivated on specially designed platforms that make cutting and shipping easier, handling costs also dropped. From a resource productivity perspective, the Dutch flower growers increased the value of their product, lowered the cost of inputs, and lowered the indirect costs of production by reducing waste and disposal expenses, thus dramatically improving their competitiveness.

Although the central focus of industrial ecology and competitive strategy should be on reducing real or "intrinsic" economic costs, in many cases, attention to resource productivity will also highlight opportunities to lower regulatory compliance burdens or other "induced" costs. DfE strategies that encourage, for example, reduced reliance on toxic chemicals may yield such benefits. A smaller inventory of hazardous materials translates into a less onerous set of waste-tracking procedures, fewer toxic release inventory forms to file, and lower regulatory costs. In many companies, however, the opportunities to cut compliance expenses are not readily apparent to managers, because the regulatory burden is not allocated directly to particular product lines but rather buried in a general overhead cost category over which line managers have little control and thus limited incentives to reduce.

Thinking in industrial ecology terms may also help improve resource productivity by enabling a company to redefine a product and thereby increase its value to customers. For example, while trying to reduce its use of chlorine bleach, Melita, a coffee filter manufacturer, found that some of its customers, fearing a dose of chlorine residue with their coffee, preferred unbleached filters (Thomas 1994). The "brown" filters represent added value in this segment of the market.

Some of the strategic benefits that a company might achieve from viewing their activities through the lens of industrial ecology are even more subtle. Producers of computer printer toner cartridges have recently begun to take back empty cartridges on terms that make it very easy for the customer (*Business Wire* 1997). This reduces the customer's waste disposal cost. It also allows the company to recapture the cartridge and to reuse it. More important, it ensures that "after market" toner cartridge producers, who might otherwise get their hands on the product and refill it and sell it, do not have ready access to a supply of cartridges. Many producers of disposable cameras seem to have missed this lesson. Rather than taking back the used camera shells from film developers, a number of major producers of disposable cameras have allowed a thriving after-market to emerge in which entrepreneurial companies acquire the discarded camera bodies and reload them (Sanders 1996). Thus the original disposable camera producers face competition from a new set of "used" disposable camera makers.

Some companies have found that by paying attention to their waste and materials flows, they have been able to uncover opportunities not only to reduce the cost within their existing production processes or to increase the value of their output, but also to create new products or services that add value beyond the process under scrutiny. DuPont, for example, has begun to manufacture pen and pencil sets out of Corian countertop scrap (Tebo 1997). This reduced the waste disposal costs from its countertop production operations and created a new product and source of revenue for DuPont. Similarly, Rhone-Poulenc found a market for the diacids that are a by-product of its nylon production (Porter and van der Linde 1995b, 125). Instead of incinerating these chemicals as waste, the company now has customers that purchase the diacids for use as coagulants in dyeing and tanning processes.

Within the Value System

Even more deeply hidden sources of opportunity can be discovered by looking to reduce costs up or down the chain of production. By forcing attention to the interdependence of the various parties in the production and distribution process and the potential for synergies among these companies (and also, as we discuss in the next section, with those beyond the production process but in physical proximity), industrial ecology can help overcome a variety of obstacles to more efficient resource use. In particular, the systems thinking that is induced can help to address imperfect information, organizational inertia, agency and control problems, and difficulties in aligning incentives in ways that optimize the value extracted from resources (Porter and van der Linde 1995a, 99). By cutting costs or generating value for suppliers or customers, companies are often able to improve their competitive position. A food wholesaler that agrees to take back and reuse packing materials, such as pallets, produces an external benefit: lower waste disposal costs for its customer. These lower costs may yield more loyal customers. Of course, the wholesaler may also be able to capture some of the value in the less wasteful packing process by charging for the take-back service (Twede 1995).

Careful analysis of environmental costs borne upstream and downstream by suppliers and customers offers real opportunities for improved competitiveness. Absent a concerted analytic effort to think through material and waste flows that go beyond the firms' boundaries, many kinds of pollution costs—and potential resource productivity gains—will remain invisible to a company. In particular, if it is not the producer that currently pays for resource misuse or inefficiency but rather the suppliers, customers, distributors, or other actors in the flow from the extraction of raw materials to the disposal of the final product at the end of its life, there is little incentive to address the problem.

But even if a company can—legally—"externalize" some part of its environmental burdens, it may not want to do so. Specifically, if a company can reduce the cost that its customer must bear, it may be able to charge more for its product, capturing the benefit of downstream waste reduction. If customers must pay for the disposal of packaging wastes, it may well be in a producer's interest to reduce the volume and weight of packing materials. The strength of incentives for upstream and downstream innovation to improve resource productivity depends on the degree of vertical integration among the various links in the chain of production, which in turn determines the transaction costs of cooperation. In a tightly integrated supply chain, the producer is very likely to be responsive to disposal costs faced by the end user. Under these circumstances, the price signals related to waste disposal down the line are transmitted relatively efficiently up the chain of production, thereby spurring efforts to refine production processes.

Where the end user is a different company from the producer but a relatively close relationship exists between supplier and customer, price signals may travel reasonably efficiently. Thus a supermarket that regularly buys products from a wholesaler may be able to induce the supplier to reduce packaging waste as part of their ongoing relationship, even if most of the benefits accrue to the store and not the distributor. Industrial ecology may help companies to focus on the needs of their upstream and downstream partners to generate gains for their common enterprise, viewed as a whole. Where, however, the relationship between customer and supplier is loose, such as in spot market sales, the producer has little incentive to attend to the needs of the end user or vice versa. In this case, the price signals do not travel very smoothly up and down the supply chain, and thus the opportunities to reduce waste, close loops, and cut costs will likely not be maximized—even if readily available ways to improve resource productivity exist.

By forcing attention to the interdependence of various parties in the production process and identifying the potential for synergies among these companies, industrial ecology can help overcome a variety of obstacles to more efficient resource use. In particular, it may promote organizational learning (Argyris and Schön 1974) or collaboration with customers and even cooperation with competitors (Brandenburger and Nalebuff 1996). Of course, if markets operated flawlessly and the economists' assumption of "perfect information" were always true, companies would have already optimized their search processes for finding these synergies. But as Porter and van der Linde (1995b) and earlier March and Simon (1958) and Nelson and Winter (1982) make clear—and everyone who makes a living as a management consultant knows—many opportunities to increase value and reduce costs remain undetected in the real world.

Beyond the Chain of Production

The opportunities to close loops in conjunction with other industrial facilities in close physical proximity but outside of one's own production chain represent another dimension of industrial ecology that offers the promise of raising resource productivity. "District heating," where one company's waste steam is diverted as a source of heat to nearby businesses or residences, offers a well-known example of the sort of symbiosis that is possible. More dramatic examples can also be found such as "eco-industrial parks" where synergistic companies share inputs, outputs, and by-products, thereby reducing waste and cutting costs. The best-documented partnership of this kind is the cooperation of Asnaes Power Company, a Novo Nordisk pharmaceutical plant, a Gyproc wallboard factory, and a Statoil refinery in Kalundbourg, Denmark (Ehrenfeld and Gertler 1997).

The Limits of Industrial Ecology

Although industrial ecology can help improve resource productivity, its stand-alone value as a guide to company strategy and competitiveness is limited. In particular, paying attention to energy and materials flows and closing loops within the production process will, in some circumstances, detract from rather than improve a company's competitive position. Three such situations come immediately into mind.

Costs Exceed Benefits

The belief in the perfection of the circle cannot be taken too far. Even when company gains and social benefits are summed, the costs of closing some loops may exceed the benefits. The recapture of water vapor, for example, may well create large private costs for any company that undertakes to do so, and is unlikely to produce benefits to society (or the company) that justify the investment. In this case, it makes sense not to close the loop—both from a company point of view and from a broader societal perspective.

The tendency of some industrial ecology advocates to overstate their case and insist on the superiority of entirely closed-loop systems is self-defeating. There are many places where a DfE approach will generate value. Conceding that, in some realms, closing loops will *not* generate value strengthens the case for industrial ecology as a corporate strategy tool. Moreover, a more nuanced theory of industrial ecology, which acknowledges its limitations and concentrates on the substantial zone of overlap with competitive strategy thinking, will be far more persuasive to the business community.

Imperfect Regulation

Because our current environmental regulatory system does not capture all of the harms that emerge from particular production and distribution processes, firms that seek to close loops and to recycle wastes that they (and their competitors) can currently legally emit—and thus externalize—will often find their competitive position diminished, not enhanced.[3] The larger the gap between the private costs faced by firms and the social costs of their activities, the less useful industrial ecology will be as a guide to firm strategy. In particular, under an imperfect regulatory system, where environmental externalities are not fully internalized, companies that invest in emissions controls or other loop-closing strategies may find themselves facing pollution costs that their competitors do not bear. In this circumstance, closing a loop may produce social benefits that exceed the social costs, but the private costs of recapturing the waste will exceed the private benefits at the company level.

But of course, as discussed above, what is perceived as "waste" (and pushed out a smokestack or effluent pipe) may in fact have some value. In other cases, environmental burdens that firms externalize do not become social costs borne by all, but rather private costs to some other party—as argued earlier in our discussion of reducing environmental impacts across the chain of production. Systems thinking, in the form of resource productivity analysis or industrial ecology, may therefore highlight this fact. It may also lead to interfirm cooperation, so long as the costs of coordination (i.e., transaction costs) are not too high, that improves both economic and environmental outcomes regardless of the imperfections in the regulatory system. Thus the gap between social costs and private costs may not be as large as some observers tend to suggest.

Policy Fragmentation

Although the goal of industrial ecology is to stimulate systems thinking across the various inputs to a production process, in some circumstances, the focus on *materials* and *energy* flows can cause a company to take its eye off the competitiveness ball. In particular, if attention to closing these particular loops is undertaken at the expense of other scarce resources, it may result in strategic disadvantage to the company. An everyday example illustrates the risk.

Using two-sided copying to produce a document will reduce paper flow. But if the document must be edited, and editorial productivity drops as a result of having to flip the two-sided copies back and forth (as the authors of this piece assert), then the emphasis on reducing materials flows, in this case paper, will come at the expense of a much more scarce and valuable resource: analytic time. By reducing editorial efficiency, the industrial ecology thinking that focused attention on the flow of paper—a relatively less scarce resource—has detracted from, not added to, the productivity of the system in question.

In the corporate context, attention to relatively unimportant resource flows can distract attention from more important contributors to productivity and competitiveness. The prospect of squandering scarce managerial time represents an obvious risk. A company might, for example, become so attentive to closing the loops in its materials and energy flows that its management will lose focus on developing new products, refining production processes, or uncovering innovations that might contribute dramatically to the corporation's ultimate value.

Conclusion

At the firm level, industrial ecology offers a promising discovery tool for enhancing resource productivity and ensuring that companies operate with optimal efficiency and profitability. Industrial ecology can promote innovation and help managers find opportunities, both inside and outside their firms, to add value to their products or to cut overall costs—and thus to improve their competitiveness. But for companies operating within our existing (imperfect) environmental regulatory structure, industrial ecology cannot be counted upon to optimize financial performance. Industrial ecology at the firm level must be seen, therefore, as a useful tool for improving resource productivity but not as an independent guide to competitive strategy.

Notes

1. Some observers look at the industry scale (Frosch and Gallopolos 1989). Others prefer to examine the flows and cycles of materials economywide (Lowe 1993; O'Rourke et al. 1996) or even across the entire planet (Socolow 1994; Ayres 1997). Still others see industrial ecology's application at the firm level (Graedel and Allenby 1995).
2. In some cases, pollution represents lost resources that can be profitably recaptured and reused, thus cutting costs and improving competitiveness. Indeed, much has been made in recent years of the opportunities for such win-win corporate interventions (Porter 1991; Gore 1992; Panayotou and Zinnes 1994; Knight 1995; Mannion 1996; Hart 1997, Parkinson 1990; Hart and Ahuja 1996). But, as we discuss below, in other cases, it will not be cost effective to close loops and recapture wastes, especially in the absence of a regulatory regime that imposes full-cost charges for releases to the air, water, or land. In brief, companies sometimes find it pays to pollute (Walley and Whitehead 1994; Nordhaus 1992).
3. Of course, firms also face bounds beyond profit maximization, including a moral obligation to operate within the expectations of the community. Increasingly, large firms recognize that this "social license to operate" serves as a constraint on the degree to which they externalize environmental harms, even if the current structure of regulatory rules and property rights might permit them to emit certain types of pollution (Esty and Gentry 1997).

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