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Toward a New Conception of the Environment-Competitiveness Relationship

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The relationship between environmental goals and industrial competitiveness has normally been thought of as involving a tradeoff between social benefits and private costs. The issue was how to balance society's desire for environmental protection with the economic burden on industry. Framed this way, environmental improvement becomes a kind of arm-wrestling match. One side pushes for tougher standards; the other side tries to beat the standards back.

Our central message is that the environment-competitiveness debate has been framed incorrectly. The notion of an inevitable struggle between ecology and the economy grows out of a static view of environmental regulation, in which technology, products, processes and customer needs are all fixed. In this static world, where firms have already made their cost-minimizing choices, environmental regulation inevitably raises costs and will tend to reduce the market share of domestic companies on global markets.

However, the paradigm defining competitiveness has been shifting, particularly in the last 20 to 30 years, away from this static model. The new paradigm of international competitiveness is a dynamic one, based on innovation. A body of research first published in *The Competitive Advantage of Nations* has begun to address these changes (Porter, 1990). Competitiveness at the industry level arises from superior productivity, either in terms of lower costs than rivals or the ability to offer products

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with superior value that justify a premium price.[1] Detailed case studies of hundreds of industries, based in dozens of countries, reveal that internationally competitive companies are not those with the cheapest inputs or the largest scale, but those with the capacity to improve and innovate continually. (We use the term innovation broadly, to include a product's or service's design, the segments it serves, how it is produced, how it is marketed and how it is supported.) Competitive advantage, then, rests not on static efficiency nor on optimizing within fixed constraints, but on the capacity for innovation and improvement that shift the constraints.

This paradigm of dynamic competitiveness raises an intriguing possibility: in this paper, we will argue that properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them. Such "innovation offsets," as we call them, can not only lower the net cost of meeting environmental regulations, but can even lead to absolute advantages over firms in foreign countries not subject to similar regulations. Innovation offsets will be common because reducing pollution is often coincident with improving the productivity with which resources are used. In short, firms can actually benefit from properly crafted environmental regulations that are more stringent (or are imposed earlier) than those faced by their competitors in other countries. By stimulating innovation, strict environmental regulations can actually enhance competitiveness.

There is a legitimate and continuing controversy over the social benefits of specific environmental standards, and there is a huge benefit-cost literature. Some believe that the risks of pollution have been overstated; others fear the reverse. Our focus here is not on the social benefits of environmental regulation, but on the private costs. Our argument is that whatever the level of social benefits, these costs are far higher than they need to be. The policy focus should, then, be on relaxing the tradeoff between competitiveness and the environment rather than accepting it as a given.

The Link from Regulation to Promoting Innovation

It is sometimes argued that companies must, by the very notion of profit seeking, be pursuing all profitable innovations. In the metaphor economists often cite, $10 bills will never be found on the ground because someone would have already picked them up. In this view, if complying with environmental regulation can be profitable, in the sense that a company can more than offset the cost of compliance, then why is such regulation necessary?

[1] At the industry level, the meaning of competitiveness is clear. At the level of a state or nation, however, the notion of competitiveness is less clear because no nation or state is, or can be, competitive in everything. The proper definition of competitiveness at the aggregate level is the average *productivity* of industry or the value created per unit of labor and per dollar of capital invested. Productivity depends on both the quality and features of products (which determine their value) and the efficiency with which they are produced.

The possibility that regulation might act as a spur to innovation arises because the world does not fit the Panglossian belief that firms always make optimal choices. This will hold true only in a static optimization framework where information is perfect and profitable opportunities for innovation have already been discovered, so that profit-seeking firms need only choose their approach. Of course, this does not describe reality. Instead, the actual process of dynamic competition is characterized by changing technological opportunities coupled with highly incomplete information, organizational inertia and control problems reflecting the difficulty of aligning individual, group and corporate incentives. Companies have numerous avenues for technological improvement, and limited attention.

Actual experience with energy-saving investments illustrates that in the real world, $10 bills are waiting to be picked up. As one example, consider the "Green Lights" program of the Environmental Protection Agency. Firms volunteering to participate in this program pledge to scrutinize every avenue of electrical energy consumption. In return, they receive advice on efficient lighting, heating and cooling operations. When the EPA collected data on energy-saving lighting upgrades reported by companies as part of the Green Lights program, it showed that nearly 80 percent of the projects had paybacks of two years or less (DeCanio, 1993). Yet only after companies became part of the program, and benefitted from information and cajoling from the EPA, were these highly profitable projects carried out. This paper will present numerous other examples of where environmental innovation produces net benefits for private companies.[2]

We are currently in a transitional phase of industrial history where companies are still inexperienced in dealing creatively with environmental issues. The environment has not been a principal area of corporate or technological emphasis, and knowledge about environmental impacts is still rudimentary in many firms and industries, elevating uncertainty about innovation benefits. Customers are also unaware of the costs of resource inefficiency in the packaging they discard, the scrap value they forego and the disposal costs they bear. Rather than attempting to innovate in every direction at once, firms in fact make choices based on how they perceive their competitive situation and the world around them. In such a world, regulation can be an important influence on the direction of innovation, either for better or for worse. Properly crafted environmental regulation can serve at least six purposes.

First, regulation signals companies about likely resource inefficiencies and potential technological improvements. Companies are still inexperienced in measuring their discharges, understanding the full costs of incomplete utilization of resources and toxicity, and conceiving new approaches to minimize discharges or

[2] Of course, there are many nonenvironmental examples of where industry has been extremely slow to pick up available $10 bills by choosing new approaches. For example, total quality management programs only came to the United States and Europe decades after they had been widely diffused in Japan, and only after Japanese firms had devastated U.S. and European competitors in the marketplace. The analogy between searching for product quality and for environmental protection is explored later in this paper.

eliminate hazardous substances. Regulation rivets attention on this area of potential innovation.[3]

Second, regulation focused on information gathering can achieve major benefits by raising corporate awareness. For example, Toxics Release Inventories, which are published annually as part of the 1986 Superfund reauthorization, require more than 20,000 manufacturing plants to report their releases of some 320 toxic chemicals. Such information gathering often leads to environmental improvement without mandating pollution reductions, sometimes even at lower costs.

Third, regulation reduces the uncertainty that investments to address the environment will be valuable. Greater certainty encourages investment in any area.

Fourth, regulation creates pressure that motivates innovation and progress. Our broader research on competitiveness highlights the important role of outside pressure in the innovation process, to overcome organizational inertia, foster creative thinking and mitigate agency problems. Economists are used to the argument that pressure for innovation can come from strong competitors, demanding customers or rising prices of raw materials; we are arguing that properly crafted regulation can also provide such pressure.

Fifth, regulation levels the transitional playing field. During the transition period to innovation-based solutions, regulation ensures that one company cannot opportunistically gain position by avoiding environmental investments. Regulations provide a buffer until new technologies become proven and learning effects reduce their costs.

Sixth, regulation is needed in the case of incomplete offsets. We readily admit that innovation cannot always completely offset the cost of compliance, especially in the short term before learning can reduce the cost of innovation-based solutions. In such cases, regulation will be necessary to improve environmental quality.

Stringent regulation can actually produce greater innovation and innovation offsets than lax regulation. Relatively lax regulation can be dealt with incrementally and without innovation, and often with "end-of-pipe" or secondary treatment solutions. More stringent regulation, however, focuses greater company attention on discharges and emissions, and compliance requires more fundamental solutions, like reconfiguring products and processes. While the cost of compliance may rise with stringency, then, the potential for innovation offsets may rise even faster. Thus the *net* cost of compliance can fall with stringency and may even turn into a net benefit.

How Innovation Offsets Occur

Innovation in response to environmental regulation can take two broad forms. The first is that companies simply get smarter about how to deal with pollution

[3] Regulation also raises the likelihood that product and process in general will incorporate environmental improvements.

once it occurs, including the processing of toxic materials and emissions, how to reduce the amount of toxic or harmful material generated (or convert it into salable forms) and how to improve secondary treatment. Molten Metal Technology, of Waltham, Massachusetts, for example, has developed a catalytic extraction process to process many types of hazardous waste efficiently and effectively. This sort of innovation reduces the cost of compliance with pollution control, but changes nothing else.

The second form of innovation addresses environmental impacts while simultaneously improving the affected product itself and/or related processes. In some cases, these "innovation offsets" can exceed the costs of compliance. This second sort of innovation is central to our claim that environmental regulation can actually increase industrial competitiveness.

Innovation offsets can be broadly divided into product offsets and process offsets. Product offsets occur when environmental regulation produces not just less pollution, but also creates better-performing or higher-quality products, safer products, lower product costs (perhaps from material substitution or less packaging), products with higher resale or scrap value (because of ease in recycling or disassembly) or lower costs of product disposal for users. Process offsets occur when environmental regulation not only leads to reduced pollution, but also results in higher resource productivity such as higher process yields, less downtime through more careful monitoring and maintenance, materials savings (due to substitution, reuse or recycling of production inputs), better utilization of by-products, lower energy consumption during the production process, reduced material storage and handling costs, conversion of waste into valuable forms, reduced waste disposal costs or safer workplace conditions. These offsets are frequently related, so that achieving one can lead to the realization of several others.

As yet, no broad tabulation exists of innovation offsets. Most of the work done in this area involves case studies, because case studies are the only vehicle currently available to measure compliance costs and both direct and indirect innovation benefits. This journal is not the place for a comprehensive listing of available case studies. However, offering some examples should help the reader to understand how common and plausible such effects are.

Innovation to comply with environmental regulation often improves product performance or quality. In 1990, for instance, Raytheon found itself required (by the Montreal Protocol and the U.S. Clean Air Act) to eliminate ozone-depleting chlorofluorocarbons (CFCs) used for cleaning printed electronic circuit boards after the soldering process. Scientists at Raytheon initially thought that complete elimination of CFCs would be impossible. However, they eventually adopted a new semiaqueous, terpene-based cleaning agent that could be reused. The new method proved to result in an increase in average product quality, which had occasionally been compromised by the old CFC-based cleaning agent, as well as lower operating costs (Raytheon, 1991, 1993). It would not have been adopted in the absence of environmental regulation mandating the phase-out of CFCs. Another example is the move by the Robbins Company (a jewelry company based in Attleboro, Massachusetts) to a closed-loop, zero-discharge system for handling the water used in plating (Berube, Nash, Maxwell and Ehrenfeld, 1992). Robbins was facing closure due to violation of its existing discharge permits. The water produced by purification through filtering and ion exchange in the new closed-loop system was 40 times cleaner than city water and led to higher-quality plating and fewer rejects. The result was enhanced competitiveness.

Environmental regulations may also reduce product costs by showing how to eliminate costly materials, reduce unnecessary packaging or simplify designs. Hitachi responded to a 1991 Japanese recycling law by redesigning products to reduce disassembly time. In the process, the number of parts in a washing machine fell 16 percent, and the number of parts on a vacuum cleaner fell 30 percent. In this way, moves to redesign products for better recyclability can lead to fewer components and thus easier assembly.

Environmental standards can also lead to innovation that reduces disposal costs (or boost scrap or resale value) for the user. For instance, regulation that requires recyclability of products can lead to designs that allow valuable materials to be recovered more easily after disposal of the product. Either the customer or the manufacturer who takes back used products reaps greater value.

These have all been examples of product offsets, but process offsets are common as well. Process changes to reduce emissions frequently result in increases in product yields. At Ciba-Geigy's dyestuff plant in New Jersey, the need to meet new environmental standards caused the firm to reexamine its wastewater streams. Two changes in its production process—replacing iron with a different chemical conversion agent that did not result in the formation of solid iron sludge and process changes that eliminated the release of potentially toxic product into the wastewater stream—not only boosted yield by 40 percent but also eliminated wastes, resulting in annual cost savings of $740,000 (Dorfman, Muir and Miller, 1992).[4]

Similarly, 3M discovered that in producing adhesives in batches that were transferred to storage tanks, one bad batch could spoil the entire contents of a tank. The result was wasted raw materials and high costs of hazardous waste disposal. 3M developed a new technique to run quality tests more rapidly on new batches. The new technique allowed 3M to reduce hazardous wastes by 10 tons per year at almost no cost, yielding an annual savings of more than $200,000 (Sheridan, 1992).

Solving environmental problems can also yield benefits in terms of reduced downtime. Many chemical production processes at DuPont, for example, require start-up time to stabilize and bring output within specifications, resulting in an initial period during which only scrap and waste is produced. Installing higher-quality monitoring equipment has allowed DuPont to reduce production interruptions and the associated wasteful production start-ups, thus reducing waste generation as well as downtime (Parkinson, 1990).

[4] We should note that this plant was ultimately closed. However, the example described here does illustrate the role of regulatory pressure in process innovation.

Regulation can trigger innovation offsets through substitution of less costly materials or better utilization of materials in the process. For example, 3M faced new regulations that will force many solvent users in paper, plastic and metal coatings to reduce its solvent emissions 90 percent by 1995 (Boroughs and Carpenter, 1991). The company responded by avoiding the use of solvents altogether and developing coating products with safer, water-based solutions. At another 3M plant, a change from a solvent-based to a water-based carrier, used for coating tablets, eliminated 24 tons per year of air emissions. The $60,000 investment saved $180,000 in unneeded pollution control equipment and created annual savings of $15,000 in solvent purchases (Parkinson, 1990). Similarly, when federal and state regulations required that Dow Chemical close certain evaporation ponds used for storing and evaporating wastewater resulting from scrubbing hydrochloric gas with caustic soda, Dow redesigned its production process. By first scrubbing the hydrochloric acid with water and then caustic soda, Dow was able to eliminate the need for evaporation ponds, reduce its use of caustic soda, and capture a portion of the waste stream for reuse as a raw material in other parts of the plant. This process change cost $250,000 to implement. It reduced caustic waste by 6,000 tons per year and hydrochloric acid waste by 80 tons per year, for a savings of $2.4 million per year (Dorfman, Muir and Miller, 1992).

The Robbins Company's jewelry-plating system illustrates similar benefits. In moving to the closed-loop system that purified and recycled water, Robbins saved over $115,000 per year in water, chemicals, disposal costs, and lab fees and reduced water usage from 500,000 gallons per week to 500 gallons per week. The capital cost of the new system, which completely eliminated the waste, was $220,000, compared to about $500,000 for a wastewater treatment facility that would have brought Robbins' discharge into compliance only with current regulations.

At the Tobyhanna Army Depot, for instance, improvements in sandblasting, cleaning, plating and painting operations reduced hazardous waste generation by 82 percent between 1985 and 1992. That reduction saved the depot over $550,000 in disposal costs, and $400,000 in material purchasing and handling costs (PR Newswire, 1993).

Innovation offsets can also be derived by converting waste into more valuable forms. The Robbins Company recovered valuable precious metals in its zero discharge plating system. At Rhone-Poulenc's nylon plant in Chalampe, France, diacids (by-products that had been produced by an adipic acid process) used to be separated and incinerated. Rhone-Poulenc invested Fr 76 million and installed new equipment to recover and sell them as dye and tanning additives or coagulation agents, resulting in annual revenues of about Fr 20.1 million. In the United States, similar by-products from a Monsanto Chemical Company plant in Pensacola, Florida, are sold to utility companies who use them to accelerate sulfur dioxide removal during flue gas desulfurization (Basta and Vagi, 1988).

A few studies of innovation offsets do go beyond individual cases and offer some broader-based data. One of the most extensive studies is by INFORM, an environmental research organization. INFORM investigated activities to prevent waste generation—so-called source reduction activities—at 29 chemical plants in California, Ohio and New Jersey (Dorfman, Muir and Miller, 1992). Of the 181 source-reduction activities identified in this study, only one was found to have resulted in a net cost increase. Of the 70 activities for which the study was able to document changes in product yield, 68 reported yield increases; the average yield increase for the 20 initiatives with specific available data was 7 percent. These innovation offsets were achieved with surprisingly low investments and very short payback periods. One-quarter of the 48 initiatives with detailed capital cost information required no capital investment at all; of the 38 initiatives with payback period data, nearly two-thirds were shown to have recouped their initial investments in six months or less. The annual savings per dollar spent on source reduction averaged $3.49 for the 27 activities for which this information could be calculated. The study also investigated the motivating factors behind the plant's source-reduction activities. Significantly, it found that waste disposal costs were the most often cited, followed by environmental regulation.

To build a broader base of studies on innovation offsets to environmental regulation, we have been collaborating with the Management Institute for Environment and Business on a series of international case studies, sponsored by the EPA, of industries and entire sectors significantly affected by environmental regulation. Sectors studied include pulp and paper, paint and coatings, electronics manufacturing, refrigerators, dry cell batteries and printing inks (Bonifant and Ratcliffe, 1994; Bonifant 1994a,b; van der Linde, 1995a,b,c). Some examples from that effort have already been described here.

A solid body of case study evidence, then, demonstrates that innovation offsets to environmental regulation are common.[5] Even with a generally hostile regulatory climate, which is not designed to encourage such innovation, these offsets can sometimes exceed the cost of compliance. We expect that such examples will proliferate as companies and regulators become more sophisticated and shed old mindsets.

Early-Mover Advantage in International Markets

World demand is moving rapidly in the direction of valuing low-pollution and energy-efficient products, not to mention more resource-efficient products with higher resale or scrap value. Many companies are using innovation to command price premiums for "green" products and open up new market segments. For example, Germany enacted recycling standards earlier than in most other

[5] Of course, a list of case examples, however long, does not prove that companies can always innovate or substitute for careful empirical testing in a large cross-section of industries. Given our current ability to capture the true costs and often multifaceted benefits of regulatory-induced innovation, reliance on the weight of case study evidence is necessary. As we discuss elsewhere, there is no countervailing set of case studies that shows that innovation offsets are unlikely or impossible.

countries, which gave German firms an early-mover advantage in developing less packaging-intensive products, which have been warmly received in the marketplace. Scandinavian pulp and paper producers have been leaders in introducing new environmentally friendly production processes, and thus Scandinavian pulp and paper equipment suppliers such as Kamyr and Sunds have made major gains internationally in selling innovative bleaching equipment. In the United States, a parallel example is the development by Cummins Engine of low-emissions diesel engines for trucks, buses and other applications in response to U.S. environmental regulations. Its new competence is allowing the firm to gain international market share.

Clearly, this argument only works to the extent that national environmental standards anticipate and are consistent with international trends in environmental protection, rather than break with them. Creating expertise in cleaning up abandoned hazardous waste sites, as the U.S. Superfund law has done, does little to benefit U.S. suppliers if no other country adopts comparable toxic waste cleanup requirements. But when a competitive edge is attained, especially because a company's home market is sophisticated and demanding in a way that pressures the company to further innovation, the economic gains can be lasting.

Answering Defenders of the Traditional Model

Our argument that strict environmental regulation can be fully consistent with competitiveness was originally put forward in a short *Scientific American* essay (Porter, 1991; see also van der Linde, 1993). This essay received far more scrutiny than we expected. It has been warmly received by many, especially in the business community. But it has also had its share of critics, especially among economists (Jaffe, Peterson, Portney and Stavins, 1993, 1994; Oates, Palmer and Portney, 1993; Palmer and Simpson, 1993; Simpson, 1993; Schmalensee, 1993).

One criticism is that while innovation offsets are theoretically possible, they are likely to be rare or small in practice. We disagree. Pollution is the emission or discharge of a (harmful) substance or energy form into the environment. Fundamentally, it is a manifestation of economic waste and involves unnecessary, inefficient or incomplete utilization of resources, or resources not used to generate their highest value. In many cases, emissions are a sign of inefficiency and force a firm to perform non-value-creating activities such as handling, storage and disposal. Within the company itself, the costs of poor resource utilization are most obvious in incomplete material utilization, but are also manifested in poor process control, which generates unnecessary stored material, waste and defects. There are many other hidden costs of resource inefficiencies later in the life cycle of the product. Packaging discarded by distributors or customers, for example, wastes resources and adds costs. Customers bear additional costs when they use polluting products or products that waste energy. Resources are also wasted when customers discard products embodying unused materials or when they bear the costs of product disposal.[6]

As the many examples discussed earlier suggest, the opportunity to reduce cost by diminishing pollution should thus be the rule, not the exception. Highly toxic materials such as heavy metals or solvents are often expensive and hard to handle, and reducing their use makes sense from several points of view. More broadly, efforts to reduce pollution and maximize profits share the same basic principles, including the efficient use of inputs, substitution of less expensive materials and the minimization of unneeded activities.[7]

A corollary to this observation is that scrap or waste or emissions can carry important information about flaws in product design or the production process. A recent study of process changes in 10 printed circuit board manufacturers, for example, found that 13 of 33 major changes were initiated by pollution control personnel. Of these, 12 resulted in cost reduction, eight in quality improvements and five in extension of production capabilities (King, 1994).

Environmental improvement efforts have traditionally overlooked the systems cost of resource inefficiency. Improvement efforts have focused on *pollution control* through better identification, processing and disposal of discharges or waste, an inherently costly approach. In recent years, more advanced companies and regulators have embraced the concept of *pollution prevention*, sometimes called source reduction, which uses material substitution, closed-loop processes and the like to limit pollution before it occurs.

But although pollution prevention is an important step in the right direction, ultimately companies and regulators must learn to frame environmental improvement in terms of *resource productivity*, or the efficiency and effectiveness with which companies and their customers use resources.[8] Improving resource productivity within companies goes beyond eliminating pollution (and the cost of dealing with it) to lowering true economic cost and raising the true economic value of products. At the level of resource productivity, environmental improvement and competitiveness come together. The imperative for resource productivity rests on the private costs that companies bear because of pollution, not on mitigating pollution's social costs. In addressing these private costs, it highlights the opportunity costs of pollution—wasted resources, wasted efforts and diminished product value to the customer—not its actual costs.

[6] At its core, then, pollution is a result of an intermediate state of technology or management methods. Apparent exceptions to the resource productivity thesis often prove the rule by highlighting the role of technology. Paper made with recycled fiber was once greatly inferior, but new de-inking and other technologies have made its quality better and better. Apparent tradeoffs between energy efficiency and emissions rest on incomplete combustion.

[7] Schmalensee (1993) counters that NO_X emissions often result from thermodynamically efficient combustion. But surely this is an anomaly, not the rule, and may represent an intermediate level of efficiency.

[8] One of the pioneering efforts to see environmental improvement this way is Joel Makower's (1993) book, *The E-Factor: The Bottom-Line Approach to Environmentally Responsible Business.*

This view of pollution as unproductive resource utilization suggests a helpful analogy between environmental protection and product quality measured by defects. Companies used to promote quality by conducting careful inspections during the production process, and then by creating a service organization to correct the quality problems that turned up in the field. This approach has proven misguided. Instead, the most cost-effective way to improve quality is to build it into the entire process, which includes design, purchased components, process technology, shipping and handling techniques and so forth. This method dramatically reduces inspection, rework and the need for a large service organization. (It also leads to the oft-quoted phrase, "quality is free.") Similarly, there is reason to believe that companies can enjoy substantial innovation offsets by improving resource productivity throughout the value chain instead of through dealing with the manifestations of inefficiency like emissions and discharges.

Indeed, corporate total quality management programs have strong potential also to reduce pollution and lead to innovation offsets.[9] Dow Chemical, for example, has explicitly identified the link between quality improvement and environmental performance, by using statistical process control to reduce the variance in processes and lower waste (Sheridan, 1992).

A second criticism of our hypothesis is to point to the studies finding high costs of compliance with environmental regulation, as evidence that there is a fixed tradeoff between regulation and competitiveness. But these studies are far from definitive.

Estimates of regulatory compliance costs prior to enactment of a new rule typically exceed the actual costs. In part, this is because such estimates are often self-reported by industries who oppose the rule, which creates a tendency to inflation. A prime example of this type of thinking was a statement by Lee Iacocca, then vice president at the Ford Motor Company, during the debate on the 1970 Clean Air Act. Iacocca warned that compliance with the new regulations would require huge price increases for automobiles, force U.S. automobile production to a halt after January 1, 1975, and "do irreparable damage to the U.S. economy" (Smith, 1992). The 1970 Clean Air Act was subsequently enacted, and Iacocca's predictions turned out to be wrong. Similar dire predictions were made during the 1990 Clean Air Act debate; industry analysts predicted that burdens on the U.S. industry would exceed $100 billion. Of course, the reality has proven to be far less dramatic. In one study in the pulp and paper sector, actual costs of compliance were $4.00 to $5.50 per ton compared to original industry estimates of $16.40 (Bonson, McCubbin and Sprague, 1988).

Early estimates of compliance cost also tend to be exaggerated because they assume no innovation. Early cost estimates for dealing with regulations concerning emission of volatile compounds released during paint application held everything

[9] A case study of pollution prevention in a large multinational firm showed those units with strong total quality management programs in place usually undertake more effective pollution prevention efforts than units with less commitment to total quality management. See Rappaport (1992), cited in U.S. Congress, Office of Technology Assessment (1994).

else constant, assuming only the addition of a hood to capture the fumes from paint lines. Innovation that improved the paint's transfer efficiency subsequently allowed not only the reduction of fumes but also paint usage. Further innovation in water-borne paint formulations without any VOC-releasing solvents made it possible to eliminate the need for capturing and treating the fumes altogether (Bonifant, 1994b). Similarly, early estimates of the costs of complying with a 1991 federal clean air regulation calling for a 98 percent reduction in atmospheric emissions of benzene from tar-storage tanks used by coal tar distillers initially assumed that tar-storage tanks would have to be covered by costly gas blankets. While many distillers opposed the regulations, Pittsburgh-based Aristech Chemical, a major distiller of coal tar, subsequently developed an innovative way to remove benzene from tar in the first processing step, thereby eliminating the need for the gas blanket and resulting in a saving of $3.3 million instead of a cost increase (PR Newswire, 1993).

Prices in the new market for trading allowances to emit SO_2 provide another vivid example. At the time the law was passed, analysts projected that the marginal cost of SO_2 controls (and, therefore, the price of an emission allowance) would be on the order of $300 to $600 (or more) per ton in Phase I and up to $1000 or more in Phase II. Actual Phase I allowance prices have turned out to be in the $170 to $250 range, and recent trades are heading lower, with Phase II estimates only slightly higher (after adjusting for the time value of money). In case after case, the differences between initial predictions and actual outcomes—especially after industry has had time to learn and innovate—are striking.

Econometric studies showing that environmental regulation raises costs and harms competitiveness are subject to bias, because net compliance costs are overestimated by assuming away innovation benefits. Jorgenson and Wilcoxen (1990), for example, explicitly state that they did not attempt to assess public or private benefits. Other often-cited studies that solely focus on costs, leaving out benefits, are Hazilla and Kopp (1990) and Gray (1987). By largely assuming away innovation effects, how could economic studies reach any other conclusion than they do?

Internationally competitive industries seem to be much better able to innovate in response to environmental regulation than industries that were uncompetitive to begin with, but no study measuring the effects of environmental regulation on industry competitiveness has taken initial competitiveness into account. In a study by Kalt (1988), for instance, the sectors where high environmental costs were associated with negative trade performance were ones such as ferrous metal mining, nonferrous mining, chemical and fertilizer manufacturing, primary iron and steel and primary nonferrous metals, industries where the United States suffers from dwindling raw material deposits, very high relative electricity costs, heavily subsidized foreign competitors and other disadvantages that have rendered them uncompetitive quite apart from environmental costs.[10] Other sectors identified by Kalt

[10] It should be observed that a strong correlation between environmental costs and industry competitiveness does not necessarily indicate causality. Omitting environmental benefits from regulation, and

as having incurred very high environmental costs can actually be interpreted as supporting our hypothesis. Chemicals, plastics and synthetics, fabric, yarn and thread, miscellaneous textiles, leather tanning, paints and allied products, and paperboard containers all had high environmental costs but displayed positive trade performance.

A number of studies have failed to find that stringent environmental regulation hurts industrial competitiveness. Meyer (1992, 1993) tested and refuted the hypothesis that U.S. states with stringent environmental policies experience weak economic growth. Leonard (1988) was unable to demonstrate statistically significant offshore movements by U.S. firms in pollution-intensive industries. Wheeler and Mody (1992) failed to find that environmental regulation affected the foreign investment decisions of U.S. firms. Repetto (1995) found that industries heavily affected by environmental regulations experienced slighter reductions in their share of world exports than did the entire American industry from 1970 to 1990. Using U.S. Bureau of Census Data of more than 200,000 large manufacturing establishments, the study also found that plants with poor environmental records are generally not more profitable than cleaner ones in the same industry, even controlling for their age, size and technology. Jaffe, Peterson, Portney and Stavins (1993) recently surveyed more than 100 studies and concluded there is little evidence to support the view that U.S. environmental regulation had a large adverse effect on competitiveness.

Of course, these studies offer no proof for our hypothesis, either. But it is striking that so many studies find that even the poorly designed environmental laws presently in effect have little adverse effect on competitiveness. After all, traditional approaches to regulation have surely worked to stifle potential innovation offsets and imposed unnecessarily high costs of compliance on industry (as we will discuss in greater detail in the next section). Thus, studies using actual compliance costs to regulation are heavily biased toward finding that such regulation has a substantial cost.[11] In no way do such studies measure the potential of well-crafted environmental regulations to stimulate competitiveness.

A third criticism of our thesis is that even if regulation fosters innovation, it will harm competitiveness by crowding out other potentially more productive investments or avenues for innovation. Given incomplete information, the limited

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reporting obvious (end-of-pipe) costs but not more difficult to identify or quantify innovation benefits can actually obscure a reverse causal relationship: industries that were uncompetitive in the first place may well be less able to innovate in response to environmental pressures, and thus be prone to end-of-pipe solutions whose costs are easily measured. In contrast, competitive industries capable of addressing environmental problems in innovative ways may report a lower compliance cost.

[11] Gray and Shadbegian (1993), another often-mentioned study, suffers from several of the problems discussed here. The article uses industry-reported compliance costs and does not control for plant technology vintage or the extent of other productivity-enhancing investments at the plant. High compliance costs may well have been borne in old, inefficient plants where firms opted for secondary treatment rather than innovation. Moreover, U.S. producers may well have been disadvantaged in innovating given the nature of the U.S. regulatory process—this seems clearly to have been the case in pulp and paper, one of the industries studied by the Management Institute for Environment and Business (MEB).

attention many companies have devoted to environmental innovations and the inherent linkage between pollution and resource productivity described earlier, it certainly is not obvious that this line of innovation has been so thoroughly explored that the marginal benefits of further investment would be low. The high returns evident in the studies we have cited support this view. Moreover, environmental investments represent only a small percentage of overall investment in all but a very few industries.[12]

A final counterargument, more caricature than criticism, is that we are asserting that any strict environmental regulation will inevitably lead to innovation and competitiveness. Of course, this is not our position. Instead, we believe that if regulations are properly crafted and companies are attuned to the possibilities, then innovation to minimize and even offset the cost of compliance is likely in many circumstances.

Designing Environmental Regulation to Encourage Innovation

If environmental standards are to foster the innovation offsets that arise from new technologies and approaches to production, they should adhere to three principles. First, they must create the maximum opportunity for innovation, leaving the approach to innovation to industry and not the standard-setting agency. Second, regulations should foster continuous improvement, rather than locking in any particular technology. Third, the regulatory process should leave as little room as possible for uncertainty at every stage. Evaluated by these principles, it is clear that U.S. environmental regulations have often been crafted in a way that deters innovative solutions, or even renders them impossible. Environmental laws and regulations need to take three substantial steps: phrasing environmental rules as goals that can be met in flexible ways; encouraging innovation to reach and exceed those goals; and administering the system in a coordinated way.

Clear Goals, Flexible Approaches

Environmental regulation should focus on outcomes, not technologies.[13] Past regulations have often prescribed particular remediation technologies—like catalysts or scrubbers to address air pollution—rather than encouraging innovative approaches. American environmental law emphasized phrases like "best available technology," or "best available control technology." But legislating as if one par-

[12] In paints and coatings, for example, environmental investments were 3.3 percent of total capital investment in 1989. According to Department of Commerce (1991) data (self-reported by industry), capital spending for pollution control and abatement outside of the chemical, pulp and paper, petroleum and coal, and primary metal sectors made up just 3.15 percent of total capital spending in 1991.

[13] There will always be instances of extremely hazardous pollution requiring immediate action, where imposing a specific technology by command and control may be the best or only viable solution. However, such methods should be seen as a last resort.

ticular technology is always the "best" almost guarantees that innovation will not occur.

Regulations should encourage product and process changes to better utilize resources and avoid pollution early, rather than mandating end-of-pipe or secondary treatment, which is almost always more costly. For regulators, this poses a question of where to impose regulations in the chain of production from raw materials, equipment, the producer of the end product, to the consumer (Porter, 1985). Regulators must consider the technological capabilities and resources available at each stage, because it affects the likelihood that innovation will occur. With that in mind, the governing principle should be to regulate as late in the production chain as practical, which will normally allow more flexibility for innovation there and in upstream stages.

The EPA should move beyond the single medium (air, water and so on) as the principal way of thinking about the environment, toward total discharges or total impact.[14] It should reorganize around affected industry clusters (including suppliers and related industries) to better understand a cluster's products, technologies and total set of environmental problems. This will foster fundamental rather than piecemeal solutions.[15]

Seeding and Spreading Environmental Innovations

Where possible, regulations should include the use of market incentives, including pollution taxes, deposit-refund schemes and tradable permits.[16] Such approaches often allow considerable flexibility, reinforce resource productivity, and also create incentives for ongoing innovation. Mandating outcomes by setting emission levels, while preferable to choosing a particular technology, still fails to provide incentives for continued and ongoing innovation and will tend to freeze a status quo until new regulations appear. In contrast, market incentives can encourage the introduction of technologies that exceed current standards.

The EPA should also promote an increased use of preemptive standards by industry, which appear to be an effective way of dealing with environmental

[14] A first step in this direction is the EPA's recent adjustment of the timing of its air rule for the pulp and paper industry so that it will coincide with the rule for water, allowing industry to see the dual impact of the rules and innovate accordingly.

[15] The EPA's regulatory cluster team concept, under which a team from relevant EPA offices approaches particular problems for a broader viewpoint, is a first step in this direction. Note, however, that of the 17 cluster groups formed, only four were organized around specific industries (petroleum refining, oil and gas production, pulp and paper, printing), while the remaining 13 focused on specific chemicals or types of pollution (U.S. Congress, Office of Technology Assessment, 1994).

[16] Pollution taxes can be implemented as effluent charges on the quantity of pollution discharges, as user charges for public treatment facilities, or as product charges based on the potential pollution of a product. In a deposit-refund system, such product charges may be rebated if a product user disposes of it properly (for example, by returning a lead battery for recycling rather than sending it to a landfill). Under a tradable permit system, like that included in the recent Clean Air Act Amendments, a maximum amount of pollution is set, and rights equal to that cap are distributed to firms. Firms must hold enough rights to cover their emissions; firms with excess rights can sell them to firms who are short.

regulation. Preemptive standards, agreed to with EPA oversight to avoid collusion, can be set and met by industry to avoid government standards that might go further or be more restrictive on innovation. They are not only less costly, but allow faster change and leave the initiative for innovation with industry.

The EPA should play a major role in collecting and disseminating information on innovation offsets and their consequences, both here and in other countries. Limited knowledge about opportunities for innovation is a major constraint on company behavior. A good start can be the "clearinghouse" of information on source-reduction approaches that EPA was directed to establish by the Pollution Prevention Act (PPA) of 1990. The Green Lights and Toxics Release Inventories described at the start of this paper are other programs that involve collecting and spreading information. Yet another important initiative is the EPA program to compare emissions rates at different companies, creating methodologies to measure the full internal costs of pollution and ways of exchanging best practices and learning on innovative technologies.

Regulatory approaches can also function by helping create demand pressure for environmental innovation. One example is the prestigious German "Blue Angel" eco-label, introduced by the German government in 1977, which can be displayed only by products meeting very strict environmental criteria. One of the label's biggest success stories has been in oil and gas heating appliances: the energy efficiency of these appliances improved significantly when the label was introduced, and emissions of sulfur dioxide, carbon monoxide and nitrogen oxides were reduced by more than 30 percent.

Another point of leverage on the demand side is to harness the role of government as a demanding buyer of environmental solutions and environmentally friendly products. While there are benefits of government procurement of products such as recycled paper and retreaded tires, the far more leveraged role is in buying specialized environmental equipment and services.[17] One useful change would be to alter the current practice of requiring bidders in competitive bid processes for government projects to only bid with "proven" technologies, a practice sure to hinder innovation.

The EPA can employ demonstration projects to stimulate and seed innovative new technologies, working through universities and industry associations. A good example is the project to develop and demonstrate technologies for super-efficient refrigerators, which was conducted by the EPA and researchers in government, academia and the private sector (United States Environmental Protection Agency, 1992). An estimated $1.7 billion was spent in 1992 by the federal government on environmental technology R&D, but only $70 million was directed toward research on pollution prevention (U.S. Congress, Office of Technology Assessment, 1994).

Incentives for innovation must also be built into the regulatory process itself. The current permitting system under Title V of the Clean Air Act Amendments, to

[17] See Marron (1994) for a demonstration of the modest productivity gains likely from government procurement of standard items, although in a static model.

choose a negative example, requires firms seeking to change or expand their production process in a way that might impact air quality to revise their permit extensively, *no matter how little the potential effect on air quality may be.* This not only deters innovation, but drains the resources of regulators away from timely action on significant matters. On the positive side, the state of Massachusetts has initiated a program to waive permits in some circumstances, or promise an immediate permit, if a company takes a zero-discharge approach.

A final priority is new forums for settling regulatory issues that minimize litigation. Potential litigation creates enormous uncertainty; actual litigation burns resources. Mandatory arbitration, or rigid arbitration steps before litigation is allowed, would benefit innovation. There is also a need to rethink certain liability issues. While adequate safeguards must be provided against companies that recklessly harm citizens, there is a pressing need for liability standards that more clearly recognize the countervailing health and safety benefits of innovations that lower or eliminate the discharge of harmful pollutants.

Regulatory Coordination

Coordination of environmental regulation can be improved in at least three ways: between industry and regulators, between regulators at different levels and places in government, and between U.S. regulators and their international counterparts.

In setting environmental standards and regulatory processes to encourage innovation, substantive industry participation in setting standards is needed right from the beginning, as is common in many European countries. An appropriate regulatory process is one in which regulations themselves are clear, who must meet them is clear, and industry accepts the regulations and begins innovating to address them, rather than spending years attempting to delay or relax them. In our current system, by the time standards are finally settled and clarified, it is often too late to address them fundamentally, making secondary treatment the only alternative. We need to evolve toward a regulatory regime in which the EPA and other regulators make a commitment that standards will be in place for, say, five years, so that industry is motivated to innovate rather than adopt incremental solutions.

Different parts and levels of government must coordinate and organize themselves so that companies are not forced to deal with multiple parties with inconsistent desires and approaches. As a matter of regulatory structure, the EPA's proposed new Innovative Technology Council, being set up to advocate the development of new technology in every field of environmental policy, is a step in the right direction. Another unit in the EPA should be responsible for continued reengineering of the process of regulation to reduce uncertainty and minimize costs. Also, an explicit strategy is needed to coordinate and harmonize federal and state activities.[18]

[18] The cluster-based approach to regulation discussed earlier should also help eliminate the practice of sending multiple EPA inspectors to the same plant who do not talk to one another, make conflicting

A final issue of coordination involves the relationship between U.S. environmental regulations and those in other countries. U.S. regulations should be in sync with regulations in other countries and, ideally, be slightly ahead of them. This will minimize possible competitive disadvantages relative to foreign competitors who are not yet subject to the standard, while at the same time maximizing export potential in the pollution control sector. Standards that lead world developments provide domestic firms with opportunities to create valuable early-mover advantages. However, standards should not be too far ahead of, or too different in character from, those that are likely to apply to foreign competitors, for this would lead industry to innovate in the wrong directions.

Critics may note, with some basis, that U.S. regulators may not be able to project better than firms what type of regulations, and resultant demands for environmental products and services, will develop in other nations. However, regulators would seem to possess greater resources and information than firms for understanding the path of regulation in other countries. Moreover, U.S. regulations influence the type and stringency of regulations in other nations, and as such help define demand in other world markets.

Imperatives for Companies

Of course, the regulatory reforms described here also seek to change how companies view environmental issues.[19] Companies must start to recognize the environment as a competitive opportunity—not as an annoying cost or a postponable threat. Yet many companies are ill-prepared to carry out a strategy of environmental innovation that produces sizable compensating offsets.

For starters, companies must improve their measurement and assessment methods to detect environmental costs and benefits.[20] Too often, relevant information is simply lacking. Typical is the case of a large producer of organic chemicals that retained a consulting firm to explore opportunities for reducing waste. The client thought it had 40 waste streams, but a careful audit revealed that 497 different

demands and waste time and resources. The potential savings from cluster- and multimedia-oriented permitting and inspection programs appear to be substantial. During a pilot multimedia testing program called the Blackstone Project, the Massachusetts Department of Environmental Protection found that multimedia inspections required 50 percent less time than conventional inspections—which at that time accounted for nearly one-fourth of the department's operating budget (Roy and Dillard, 1990).

[19] For a more detailed perspective on changing company mindsets about competitiveness and environmentalism, see Porter and van der Linde (1995) in the *Harvard Business Review.*

[20] Accounting methods that are currently being discussed in this context include "full cost accounting," which attempts to assign all costs to specific products or processes, and "total cost accounting," which goes a step further and attempts both to allocate costs more specifically and to include cost items beyond traditional concerns, such as indirect or hidden costs (like compliance costs, insurance, on-site waste management, operation of pollution control and future liability) and less tangible benefits (like revenue from enhanced company image). See White, Becker and Goldstein (1991), cited in U.S. Congress, Office of Technology Assessment (1994).

waste streams were actually present (Parkinson, 1990). Few companies analyze the true cost of toxicity, waste, discharges and the second-order impacts of waste and discharges on other activities. Fewer still look beyond the out-of-pocket costs of dealing with pollution to investigate the opportunity costs of the wasted resources or foregone productivity. How much money is going up the smokestack? What percentage of inputs are wasted? Many companies do not even track environmental spending carefully, or subject it to evaluation techniques typical for "normal" investments.

Once environmental costs are measured and understood, the next step is to create a presumption for innovation-based solutions. Discharges, scrap and emissions should be analyzed for insights about beneficial product design or process changes. Approaches based on treatment or handling of discharges should be accepted only after being sent back several times for reconsideration. The responsibility for environmental issues should not be delegated to lawyers or outside consultants except in the adversarial regulatory process, or even to internal specialists removed from the line organization, residing in legal, government or environmental affairs departments. Instead, environmental strategies must become a general management issue if the sorts of process and product redesigns needed for true innovation are to even be considered, much less be proposed and implemented.

Conclusion

We have found that economists as a group are resistant to the notion that even well-designed environmental regulations might lead to improved competitiveness. This hesitancy strikes us as somewhat peculiar, given that in other contexts, economists are extremely willing to argue that technological change has overcome predictions of severe, broadly defined environmental costs. A static model (among other flaws) has been behind many dire predictions of economic disaster and human catastrophe: from the predictions of Thomas Malthus that population would inevitably outstrip food supply; to the *Limits of Growth* (Meadows and Meadows, 1972), which predicted the depletion of the world's natural resources; to *The Population Bomb* (Ehrlich, 1968), which predicted that a quarter of the world's population would starve to death between 1973 and 1983. As economists are often eager to point out, these models failed because they did not appreciate the power of innovations in technology to change old assumptions about resource availability and utilization.

Moreover, the static mindset that environmentalism is inevitably costly has created a self-fulfilling gridlock, where both regulators and industry battle over every inch of territory. The process has spawned an industry of litigators and consultants, driving up costs and draining resources away from real solutions. It has been reported that four out of five EPA decisions are currently challenged in court (Clay, 1993, cited in U.S. Congress, Office of Technology Assessment, 1994). A study by the Rand Institute for Civil Justice found that 88 percent of the money paid out between 1986 and 1989 by insurers on Superfund claims went to pay for legal and administrative costs, while only 12 percent were used for actual site cleanups (Acton and Dixon, 1992).

The United States and other countries need an entirely new way of thinking about the relationship between environment and industrial competitiveness—one closer to the reality of modern competition. The focus should be on relaxing the environment-competitiveness tradeoff rather than accepting and, worse yet, steepening it. The orientation should shift from pollution control to resource productivity. We believe that no lasting success can come from policies that promise that environmentalism will triumph over industry, nor from policies that promise that industry will triumph over environmentalism. Instead, success must involve innovation-based solutions that promote both environmentalism and industrial competitiveness.

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