CHAPTER 5

Regulation and Innovation

BECAUSE INNOVATION—the development and adoption of new technology—is essential to U.S. economic performance over time, regulation that interferes with innovation, however justifiable on other grounds, comes at a cost. Therefore, in such areas as competition policy, environmental regulation, and electric power restructuring, the Administration has worked to ensure that regulation not only does not interfere with innovation, but indeed fosters beneficial technological change and adapts itself to such change as well.

Appropriately designed regulation can achieve desirable outcomes that unconstrained commercial activity would not produce. Historically, regulation in the United States has been selectively applied both to certain types of undesirable economic behavior and to certain effects of that behavior. Antitrust laws, for example, promote competition and prohibit anticompetitive actions that interfere with market performance. Industry-specific economic regulation has traditionally constrained the exercise of market power by natural monopolies such as telephone companies and electric utilities. Environmental regulation, for its part, has targeted the side effects of economic activity on the health of people and of the environment.

Although regulation, when wisely applied, can prevent economic harm and protect economic benefits, real productivity gains over time depend on innovation—on the steady flow of new ideas, products, and processes. Over the past 50 years, more than half of all productivity gains in the U.S economy, as measured by output per labor hour, have come from innovation and technical change. Innovation thus boosts all sectors of the economy; it is important for agriculture just as it is for semiconductors. Those industries that fall under the rubric of high technology–including aerospace, telecommunications, biotechnology, and computers–provide particularly dramatic examples of growth through innovation: their combined share of manufacturing output has increased by more than half since 1980. Indeed, high-technology products have become an increasingly important part of everyday life for American consumers. The spread of Internet use in the past 6 years, from a few specialized applications to a routine tool for tens of millions of Americans, is one notable illustration. But it is through innovative effort economy-wide, both public and private, that the United States has succeeded in strengthening its position as the world leader in research and development (R&D; Box 5-1). To take just one measure, the number of patents granted in the United States grew to more than 140,000 in 1998, after passing the 100,000 mark for the first time in 1994.

Given the economic importance of innovation, public policy can achieve greater good when it extends its perspective beyond the immediate goals of particular regulatory programs and takes into account the effects of regulation on the development and adoption of new technology. This chapter first addresses how U.S. antitrust policy, beyond its conventional focus on the price and output benefits of competition, has

Box 5-1.—The Scope of Government Support of R&D

The Federal Government supports innovative activity in both direct and indirect ways. And it does so in no small measure: data from 1997 show that U.S. Government agencies provide about 30 percent of all funds spent on R&D in the United States. The government's share of funds for basic research (research that advances scientific knowledge but has no immediate commercial objectives) is higher still, at about 57 percent. The National Institutes of Health (NIH), for example, are a principal source of funding for biomedical research. NIH programs provide resources for such projects as AIDS/HIV treatment, cancer research, and the Human Genome Project. The government has also taken a direct role in R&D and scientific education through the National Science Foundation and other agencies such as the Department of Energy, which oversees the large complex of Federal laboratories. Federally funded research has been responsible for major developments in space technology, defense systems, energy, medicine, and agriculture, to list just a sample. Federal agencies face the continuous challenge of matching their missions to the technological needs of an evolving world.

Industry provides most of the remaining 70 percent of R&D funding in the United States. Indeed, its proportion has grown steadily in the past decade, to about two-thirds of the total. But government plays a role—an indirect one—in this effort as well, for example through tax incentives that encourage innovation. The research and experimentation tax credit, which allows firms to reduce their tax obligations by 20 percent of qualifying R&D expenditure, was recently extended until June 1999. The government also supports basic research that underlies many applied advances in private industry, and it engages in partnerships with institutions such as universities to share the risk of long-term R&D efforts that have the potential to create widespread benefits.

incorporated consideration of the long-run benefits of innovation. The chapter then examines how alternative ways of implementing environmental regulation affect the innovation and diffusion of new technology. Finally, the restructuring of the electric power industry is presented as an illustration of how technological change affects the desired form of regulation, and how regulatory changes in turn affect the pace and direction of new technological and market developments.

COMPETITION POLICY AND INNOVATION

Innovation makes enormous contributions to the Nation's economic growth, not just in the large and growing high-technology sector but across all sectors of the economy. The impact of new technologies goes beyond expanding the range of choices for consumers and lowering prices; often, new ideas have significant consequences for the very structure and performance of markets. In turn, one firm's competitive strategy and market behavior can affect the incentive and the ability of all firms in an industry to produce innovative goods and services, sometimes for the worse. The reciprocal effects of technological innovation on markets, and of markets on innovation, pose ongoing challenges for antitrust policy. The antitrust authorities have not shied from these challenges: 1998 saw the continued application of the antitrust laws in technologically complex industries, and renewed attention to the economic benefits of innovation in assessing the health of these vital markets.

MERGER REVIEW AND INNOVATION

Corporate merger activity continues at a swift pace: in fiscal 1998 over 4,000 merger notifications were filed with the Antitrust Division of the Justice Department and the Federal Trade Commission, the two Federal agencies concerned with antitrust. About 7,000 additional mergers were valued at less than $10 million, the level at which premerger notification is required. The total value of all mergers in 1998 is estimated at over $1.6 trillion. The scope of merger activity in 1998 is comparable, depending on the measure used, to that experienced at the turn of the century and in the late 1980s. Although, as in other years, most of these mergers were small, the recent wave of economic consolidation has been distinguished by the number of very large mergers and by the number of mergers in such highly innovative sectors as telecommunications, aerospace, and biotechnology. These transactions, in addition to simply creating bigger firms, sometimes create measurably more concentrated markets. Given the importance of these advanced industrial sectors for future growth, a pressing question for antitrust authorities has been how such changes in market concentration and firm size affect innovative activity.

The United States has a decades-long history of enforcing its antitrust laws to ensure that mergers, acquisitions, and other structural changes in firms and markets do not unduly empower the resulting enterprises to raise prices or restrict output. The use of antitrust policy as a framework for preserving and encouraging innovation, however, is a more recent development, on which there is less consensus. The relationship between an industry's market structure and the amount of innovative activity in that industry may differ from the relationship between market concentration and short-term price competition, the conventional focus of antitrust. Whereas concentration nearly always weakens price competition, its effects on innovation are less clear-cut. Antitrust authorities investigating today's mergers thus confront a difficult task: they must not only assess the likely effects of consolidation on prices and output in the relevant product market, but also account for a merger's potential impact on innovation and the benefits it promises to consumers in the long run.

DO BIGGER FIRMS HELP OR HURT INNOVATION?

Several recent mergers are notable for their sheer size. In the last few years the financial services, telecommunications, and petroleum industries have all seen mergers or proposed mergers valued in the tens of billions of dollars. Antitrust policy in the United States does not, however, generally treat firm size per se as important for determining the strength of competition. Market share, which does not necessarily correlate with size, is understood to be the more relevant determinant of whether prices and quantities are set competitively.

There has been greater debate, however, about the relevance of firm size for *innovation*. Indeed, one could make perhaps as strong a theoretical case that bigness is good for innovation as that it is bad or indifferent. Some commentators, following the economist Joseph Schumpeter, have praised large enterprises for their superior ability to attract the financial and human capital, bear the risk, and recoup the investment required for sustained research and development (R&D) activities. Small firms, on the other hand, have been touted as more creative and more nimble in adapting to changes and opportunities than their larger, more bureaucratic counterparts.

Empirical studies have consistently found that big enterprises are more likely than small ones to undertake at least some R&D. In addition, among those firms that do undertake R&D, bigger firms tend to make larger R&D investments. Beyond a threshold level of size, however, it is less evident that larger firms' R&D investments are *proportionately* greater than those made by smaller firms. Most recent research supports the consensus view that, in general, R&D rises only proportionately with firm size.

Data matching R&D investment with the number of patents generated have shown that smaller firms produce more innovations per

R&D dollar than do large firms. But these results do not necessarily imply that large firms are less desirable from an innovation standpoint. First, not all patents are equivalent in value, and not all successful R&D is patented. So simply counting patents is an imperfect measure of innovative productivity.

Second, there may be diminishing returns to R&D. Big firms, because of their greater resources and ability to diversify, may simply be more willing to risk investing in projects that appear to have less prospect of success. Some of these projects do succeed, making discoveries that smaller firms might have missed.

Finally, large firms may earn higher returns on their R&D than small ones because they can deploy innovations across a broader array of products, or take advantage of process cost savings over a larger production volume. This may explain why large firms continue to invest in R&D even after their proportionate patent yield drops below that of smaller firms.

In short, although available data and research do call into question the conjecture that large firms are superior innovators, they do not necessarily support the contrary view that large firms are bad for technological progress and economic growth. The evidence suggests that the large firms created by some recent mergers will have no special tendency—but likewise no special reluctance—to engage in innovation.

MARKET CONCENTRATION, COMPETITION, AND INNOVATION

The focus on market share in U.S. competition policy fits logically with antitrust's basic premise that economic performance improves with competition. Of course, exception is made for industries that are natural monopolies, in which costs per unit of output decline as a firm's production increases, to the point that it is most efficient to have just one firm produce all output. In such markets, which historically have included railroads, electric power, and telecommunications, monopoly may actually be better for consumers, so long as the monopolist can be prevented from abusing its power to raise prices or stifle innovation by potential competitors. Competition in such cases would require wasteful duplication of facilities—parallel sets of railroad tracks, or duplicate sets of wires connecting houses to the electric power grid or the telephone network. For this reason natural monopolies have generally been allowed to operate but subjected to strict regulation. In most industries, however, economic theory and antitrust policy have long seen more rather than less competition as best serving the purpose of lowering prices, expanding output, and making consumers better off.

The presumption in favor of greater competition becomes less universal when the policy goal is not just lower prices for a given set of goods produced under a fixed set of technologies, but also the preservation of efficient innovative activity by firms over time. As a theoretical matter, depending on various conditions, either monopoly power or competition may yield the greater amount of innovation. On the one hand, rivalry over market share gives competitive firms an incentive to develop new products and processes that will help them improve or defend their market position. On the other hand, competitive firms face greater risk in their investments in innovation than do those with market power. Even if a firm does make a potentially profitable discovery, and even if it can establish intellectual property rights over that discovery that give it a temporary monopoly, rivals may soon develop similar or better advances that diminish or negate its value. The risk that a competing firm's successful innovations will trump one's own grows with the number of competitors, and the expected return to innovation may fall to the point where it does not justify the cost.

Firms in competition also face more-binding financial constraints. A monopolist or other firm with market power probably has, or can raise, more cash for R&D and has a better chance of recouping its R&D investment. Large, established firms might be particularly adept at marshaling resources for incremental innovation or for helping to bring a small firm's invention to market.

Even a monopolist—especially an unregulated one—has an incentive to engage in cost-reducing innovations. But because a monopolist already has the market share for which competitive firms strive, it may have less incentive to pursue product innovations and improvements than do firms facing competition. Further, a monopolist will have an incentive to innovate strategically to protect its monopoly by excluding rivals and by avoiding cannibalization of its existing business. This may lead it to delay implementation of those innovations it does develop. A monopolist might therefore be a qualitatively inferior innovator from the perspective of consumers and overall economic welfare. A dominant firm may also have an incentive to deter others from engaging in innovative activity that threatens its market power. The result could be a shift in the industry-wide pattern of innovation that makes everyone except the dominant firm worse off.

The findings of empirical studies do not resolve this ambiguous theoretical relationship between competition and innovation. Some studies find innovation to be most intense among firms in oligopoly markets that provide a mix of competitive incentives and above-competitive returns. Other studies find no such correlation. To the extent there is consensus, it is that neither the presence of many competitors nor pure monopoly correlates systematically with optimal levels of innovation. But even in such polar cases, predictions about R&D activity are hard to make. The determination requires looking at the facts in each case, because market factors other than concentration, as well as a firm's regulatory status and the nature of its products and technologies, also affect innovation.

In some industries, fierce competition yields substantial R&D: dozens of firms today are racing to develop new antiobesity drugs, for example. But monopolies can be energetic innovators, too: during AT&T's decades of dominance of the telecommunications industry, its Bell Laboratories research arm developed a steady stream of new technologies. In each case factors independent of market structure made the difference. The market for antiobesity drugs is new, the rewards for successful R&D are huge—future sales could reach an estimated $5 billion per year—and the efficient level of R&D investment could be quite high. In the case of AT&T, although innovation in telecommunications might have been greater under competition, consumer demand for increased capabilities in the telephone system, opportunities to enter new markets, and the guarantee of steady, regulated returns that could help fund risky R&D made complacency undesirable even for an established monopolist.

In addressing innovation, antitrust policy must therefore temper the strong presumption in favor of competition that applies in conventional analysis of short-run price and output levels. Although more rivalry rather than less will often remain the rule of thumb, enforcement authorities cannot as confidently presume as a matter of economic theory that more competition is good or that market power is bad for R&D. When the overall level and the future path of innovation are at issue, case-by-case analysis of the economic facts is likely to be even more vital than in conventional antitrust investigations.

MERGER POLICY IN HIGH-TECHNOLOGY MARKETS

The puzzles posed by the economics of innovation have not deterred the antitrust authorities from investigating how mergers in several U.S. industries would affect the flow of new ideas, products, and processes. They have, however, taken a deliberate, measured approach to their investigations. Recent enforcement decisions have taken into account both the traditional presumptions about competition and the inability to rely on those presumptions when it comes to promoting innovation. But they also reflect careful consideration of the ambiguous effects that firm size and market structure may have on innovation. Thus, although the antitrust authorities have recognized the need for a dynamic perspective on mergers and have not refrained from enforcement based on concerns about innovation, they have brought such actions only where changes in market concentration were extreme and, generally, where other evidence of effects on innovation was present.

Early Cases

One of the first enforcement actions motivated by innovation concerns occurred in 1990, when the Federal Trade Commission (FTC) challenged the acquisition of Genentech, Inc., by the Swiss-based company Roche Holdings, Ltd. Some of the issues raised in that case were traditional questions about reduction of competition: for example, Roche was on the verge of becoming a major challenger to Genentech's dominant position in the market for products to treat human growth hormone deficiency. But more central to the Commission's complaint was that Roche and Genentech were actual—not just potential—competitors in the development of some other important therapeutic innovations, especially for the treatment of AIDS and HIV infection. Concerns about dynamic effects on the market and on the pace of innovation, not about short-term price or output levels, drove the enforcement decision.

The Justice Department's Antitrust Division first challenged a merger on innovation grounds in 1993, when it investigated the proposed acquisition of General Motors' Allison Transmission Division by ZF Friedrichshafen, a German company. Allison and ZF together produced 85 percent of world output of heavy-duty automatic transmissions for trucks and buses, but they actually competed head to head in only a few geographic markets. The Justice Department nonetheless concluded that even markets whose concentration would be unaffected by the merger would be harmed by the combined company's reduced incentive to develop new designs and products, and it therefore moved to block the transaction.

These two cases differ in important ways, and each establishes a significant precedent for factoring innovation effects into competition policy. In reaching its decision to challenge Roche's acquisition of Genentech, the FTC did not have to predict that the resulting increased concentration in the biotechnology industry would reduce innovation. Rather, the increase in concentration was accompanied by concrete evidence that Roche was at an advanced stage in developing a competing human growth hormone treatment, and that Roche and Genentech were among a small group of companies racing to develop certain AIDS/HIV treatments. The merger would thus have concentrated actual, not merely potential or speculative, R&D efforts.

The Justice Department's action in the ZF/Allison case was in one respect bolder. There was no specific R&D effort that the Antitrust Division found would be compromised by the acquisition. But the decision indicates that where the consolidation is so great as to leave an industry near monopoly and without other potential sources of new developments, potential harm to the "innovation market" could justify challenging the transaction. These two factors—very high levels of concentration and evidence of parallel and competing innovation efforts—have also formed the basis for several recent actions through which the relationship between antitrust and innovation has further developed.

Aerospace

The aerospace industry is one of the most innovative in the United States. Its market is characterized by high concentration but also, outside the defense sector, by international competition. In the past 2 years the FTC has approved one major aerospace merger, and the Justice Department has blocked another. Innovation considerations are central to explaining both these enforcement decisions.

In 1997 the FTC approved the merger of Boeing Co. and McDonnell Douglas Corp., the two largest commercial aircraft manufacturers in the United States. In that case, analysis of innovation in the aerospace industry supported the merger, not because the transaction was expected to increase R&D, but because the analysis showed that McDonnell Douglas had fallen behind technologically and could no longer exert competitive pressure on Boeing or its overseas rivals. Acquisition by Boeing would therefore not reduce competition and would allow McDonnell Douglas' assets to be put to better use by a more technologically advanced enterprise.

Concerns about progress in aerospace innovation led to the opposite conclusion in Lockheed Martin Corp.'s proposed acquisition of Northrop Grumman Corp., first announced in 1997. The Justice Department's challenge to the merger last year noted that Lockheed and Northrop were two of the leading suppliers of aircraft and electronics systems to the U.S. military. The Department concluded that the merger would give Lockheed a monopoly in fiberoptic towed decoys and in systems for airborne early warning radar, electro-optical missile warning, and infrared countermeasures. In addition, the merger would reduce the number of competitors in high-performance fixed-wing military airplanes, on-board radiofrequency countermeasures, and stealth technology from three to two. The agency contended that consolidation in these markets would lead to higher prices, higher costs, and reduced innovation for products and systems required by the U.S. military.

Although traditional competitive concerns about prices were an important part of the challenge to this acquisition, concerns about innovation were central. For example, the Justice Department noted that both Lockheed and Northrop had launched R&D efforts in advanced airborne early warning radar systems, and it concluded that consolidation of the two efforts would harm future military procurement. The Department also found evidence that competition is particularly important for technological advances in high-performance military aircraft. It thus concluded that "competition is vital to maximize both the innovative ideas associated with each military aircraft program, as well as the quality of the processes used to turn innovative ideas into cost-effective, technically sound, and efficiently produced aircraft."

The antitrust authorities' linking of competition to innovation in the Lockheed/Northrop case was a cautious one. Two factors weighed heavily toward blocking the transaction. First, there was evidence that Lockheed and Northrop either were actually conducting competing R&D on relevant products or were the leading contenders to conduct such R&D in the future. Second, there was evidence that their consolidation would lead to either monopoly or substantial dominance in relevant product markets, not just reducing but in large part eliminating competitive pressure. Thus, a combination of market structure and the existence of parallel innovation efforts pointed toward a likely reduction in innovative activity if the merger were consummated.

Biotechnology and Pharmaceuticals

The FTC recently focused on innovation concerns in crafting a consent agreement with two merging firms in the biotechnology and pharmaceuticals industry. In 1996 Ciba-Geigy Ltd. and Sandoz Ltd., two Swiss firms with substantial U.S. operations, announced plans to merge into a new company, to be known as Novartis. The FTC raised several objections to the merger. Some of the objections concerned traditional antitrust matters: the FTC was concerned that the combination would give the merged entity power to reduce competition and raise prices in the market for herbicides used in growing corn and in that for flea-control products for pets. The FTC accordingly ordered that one party divest its businesses in those markets as a condition for its approval. The more novel parts of the Commission's challenge, however, had to do with the prospects for innovation in the market for gene therapy products, which allow treatment of diseases and medical conditions by modifying genes in patients' cells.

At the time of the FTC's investigation, in 1996 and 1997, no gene therapy products were yet on the market; indeed, none had even been approved by the Food and Drug Administration. Conventional antitrust analysis therefore did not apply, because there was no product market in which to analyze the merger's effects on prices and output. The Commission instead adopted a dynamic perspective: looking to the future, it found two reasons for long-run competitive concerns. First, the market for gene therapy products is expected to grow rapidly, with annual sales of $45 billion projected by 2010. Second, Ciba and Sandoz were among a very few firms with the technological capability and rights to intellectual property necessary to develop gene therapy products commercially. Together they would control essential patents, know-how, and proprietary commercial rights without which other firms, even if they did eventually develop gene therapy products, would be unable to commercialize them.

The FTC concluded that "preserving long-run innovation in these circumstances is critical." The Commission did not, however, block the merger. Instead, it crafted a consent decree designed to correct those aspects of the transaction that raised concerns for current and future competition. As noted, the Commission required divestiture of certain overlapping herbicide and flea-control businesses. More interestingly, the Commission did not require divestiture of either firm's gene therapy division. Instead, Ciba and Sandoz agreed to license technology and patents sufficient to allow one of their rivals to compete against the merged entity in the development of gene therapy products.

The Commission's remedy steered between the potentially conflicting economic effects that a merger can have on R&D. On the one hand, consolidating complementary capabilities can enhance innovation and allow a combination of firms to achieve what the same firms could not have achieved separately. On the other hand, concentrating markets to near-monopoly levels can dampen the pressure to innovate and reduce the enhanced probability of success that comes from multiple R&D efforts. The Commission declined to order either Ciba or Sandoz to divest its gene therapy subsidiary because it found that the R&D efforts of the parent companies and their subsidiaries were closely coordinated, so that divestiture would have been disruptive and counterproductive for innovation. The decision instead to order compulsory licensing to a capable competitor was designed to preserve both market competition and the benefits of the merging parties' relationships with each other and their respective gene therapy subsidiaries.

The market context in this case is significant. Ciba and Sandoz were not merely two of several viable competitors in the relevant market; their merger did not simply change the degree of competition within a middling range of market concentration. Rather, their combination concentrated virtually all innovation capability and essential inputs for the commercialization of gene therapy under one corporate roof. Innovation concerns became sufficient to motivate intervention because the facts showed a combination of monopoly market structure and a reduction in the number of potential innovation efforts. These provided sound economic support for the use of competition policy to preserve the impetus for technological progress. But the FTC's action also broke important new ground: it expressly recognized that a current merger could be challenged on grounds of future innovation and competition in a product market that does not yet—but likely will—exist.

INTELLECTUAL PROPERTY AND ANTITRUST

As the above discussion of merger review demonstrates, the incorporation of innovation concerns into antitrust enforcement often involves intellectual property issues. The purpose of intellectual property protection is to encourage people to bring inventions and other creative works into the marketplace. In so doing it furthers, in the words of the U.S. Constitution, "the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries." To be sure, not all inventors or artists are motivated by economic gain. But in many cases the decision to devote time and resources to risky, innovative projects or to invest in publication will hinge on the ability to profit from success.

Patents in the United States accordingly confer limited rights to exclude others, even those who have come up with the same idea independently, from making, selling, or using a covered invention without the patentholder's consent. Patenting allowed Eli Whitney to capture the profits his cotton gin made possible, just as today it allows an electrical engineer to secure her rights to the returns on an advance in computer technology. Copyright statutes similarly provide protection against unauthorized copying of original works in a variety of media (including electronic media; see Box 5-2), even if the copying is not literal or exact. Only Thelonious Monk (or the record company to which he sold the rights) could freely record "'Round Midnight"; only a software developer (or a manufacturer to which the developer grants a license) has exclusive rights to copy and sell its programs commercially. Finally, trademark laws can be used to protect brand recognition. One restaurant entrepreneur cannot misleadingly use another restaurant's name for his own new business; a new soft drink's label cannot look too much like the market leader's.

On the surface, a tension exists between intellectual property protection and competition policy: one grants exclusive rights that confer a limited, temporary monopoly; the other seeks to keep monopoly at bay. But at a more basic level the two areas of policy have a common goal: to enhance economic performance and consumer welfare. For that reason patents, for example, are extended only to novel, nonobvious, and useful inventions and are limited in duration to 20 years. Copyrights are granted for the life of the author plus 70 years.

Once an innovative product has been developed, efficiency dictates that it be produced competitively. So patents should not provide a greater incentive to invent than is necessary to get the invention into the stream of commerce. The limits on the duration, scope, and availability of patents implicitly balance the benefits of preserving incentives to innovate against the efficiency costs of granting exclusive rights. A similar balance between innovation and competition appears in U.S. antitrust policy, which recognizes that innovation sometimes benefits from cooperation among competitors (Box 5-3). The National Cooperative Research and Production Act, for example, reduces potential antitrust liability for qualifying R&D and production joint ventures. In fiscal 1998, 38 such joint ventures registered with the Department of Justice and the FTC, bringing to over 750 the number of registrations since the statute was passed in 1984.

Similarly, the 1995 Antitrust Guidelines for the Licensing of Intellectual Property acknowledge the exclusivity conferred by intellectual property protection but recognize that patents do not necessarily

Box 5-2.—Electronic Commerce and Digital Copyright Protection

More than 70 million Americans now have access to the Internet, which they use in no small part for commercial activities, including the purchase of music, video, software, text, and other information goods that can now be sent directly from one computer to another. The volume of this electronic commerce exceeded $10 billion in 1998 and is predicted to reach $300 billion within a few years. Electronic commerce provides unprecedented opportunity for firms and individuals to sell and distribute such digital goods widely and quickly. But with these benefits comes risk: the ease with which a recording company can deliver a new song to buyers electronically is matched by that with which buyers can illegally copy and resell it. For electronic commerce to reach its potential, sellers must be sure that their products are legally protected from such piracy.

New copyright legislation has taken steps to protect digital goods and so encourage innovative commercial uses of electronic media. The 1998 Digital Millennium Copyright Act makes it a crime to break the "digital wrappers" that protect electronically encrypted intellectual property, or to sell equipment designed to penetrate such encryption. This increased protection of digital goods will help spur commerce and innovation, but it may also unduly restrict legitimate uses of copyrighted material. For example, the fair use doctrine allows free access to copyrighted works for limited personal, educational, and research purposes that do not compromise the work's commercial value. What has traditionally been prohibited is not access to the copyrighted work, but rather its indiscriminate copying and distribution. An absolute ban on bypassing digital wrappers might allow publishers to impose a per-use fee on publications in digital format. This would block free access to such works and thus erode the fair use principle. The 1998 Digital Millennium Copyright Act attempts to balance the need to preserve commercial incentives with the right to fair use by permitting anyone who cannot get access to materials usually covered by the fair use doctrine to petition the Librarian of Congress for an exemption from the statute.

confer market power and that licensing of intellectual property is generally procompetitive. Licensing and other arrangements for transferring patents or copyrights can help bring complementary factors of production together and thus allow faster and more efficient use of new inventions. This benefits consumers by reducing costs and encouraging the introduction of new products. Under the guidelines, the FTC and

Box 5-3.—Cooperative Innovation and the Y2K Problem

As explained in Chapter 2, many older computer programs encode years using only the last two digits and will not properly interpret "00" as "2000" when the year 2000 arrives. This "year 2000" (Y2K) problem may cause data to be lost and programs and systems to fail worldwide. The risks are particularly acute in industries where different firms' computer systems are highly interdependent. Accordingly, once the extent of the problem was recognized, a number of manufacturing firms and securities firms proposed, through their trade associations, to exchange information among themselves and their computer services suppliers that would expedite resolution of the problem in their industries. Participating firms would share information gathered from manufacturers about efforts to make chips, other hardware, and software compliant with Y2K demands, and would exchange the results of product tests, successful remedies, and information about the sources of various computer products.

The competitive concerns raised by the prospect of such collaboration were multifaceted. For example, securities firms compete with each other not just in the provision of financial services, relevant information for which is stored in each company's computers, but also in the procurement of computer systems. Exchange of information about products and the results of various tests could potentially be used by rivals as a vehicle for fostering and monitoring collusion in both areas of competition. At the same time, computer hardware manufacturers and software developers compete in the development of new products and in innovating around

the Department of Justice balance these benefits case by case against the risk that a particular licensing arrangement could reduce competition in the product market or in the development of new technologies.

For example, in 1997 the Justice Department concluded that an agreement to package certain patents essential for advanced video-compression technology into a single license was permissible because the patents were complements and because the licenses, which would be granted on a nondiscriminatory basis, were unlikely to facilitate collusion or the exercise of market power. But in another action the FTC required recision of an agreement that pooled patents for laser systems used in eye surgery because the partners in the deal were the only independent competitors in the market for that equipment prior to the pooling arrangement. Recently, the Justice Department successfully concluded its 1996 challenge to a license that granted a hospital access to software necessary to repair medical imaging equipment only if the hospital agreed not to compete with the licensor in providing repair

Box 5-3.—*continued*

challenges like the Y2K problem. The proposed information exchange could give these firms competitively valuable details about their rivals' product developments or terms of sale to customers, undermining competition and opening the door for collusion here as well.

Collaboration on the Y2K problem also offered clear benefits, however. A joint effort would avoid duplicative equipment testing and information gathering, allow more efficient identification of successful remedies, and permit faster and more accurate responses to computer system vendors about remaining problems. Manufacturers could devote resources to product improvement that would otherwise have been devoted to exchanging information.

The Justice Department stated in its letters reviewing the proposed collaborations, issued July 1 and August 14, 1998, that it did not foresee grounds for enforcement action, because the proposals contained sufficient safeguards that the benefits of cooperation outweighed the risks to competition. The firms agreed to cooperate without exchanging price or customer information that could be used to restrain competition. And computer manufacturers would receive test information about their own products only, not those of their rivals. Although the Justice Department recognized that the information exchanges could still affect competitive strategy, it concluded that the agreements were unlikely to lessen innovation or pricing rivalry among vendors and offered real prospects for reducing the costs and increasing the speed of a resolution to the Y2K problem.

services to third parties. These cases reflect careful monitoring by the antitrust authorities of the interaction among intellectual property protection, competition, and innovation.

NETWORK COMPETITION AND INNOVATION

Antitrust policy in the United States has devoted substantial attention in the past year to the relationship between competition and innovation in what are today called network industries. Enforcement actions in the credit card and software industries as well as consent decrees in the telecommunications industry have highlighted the challenges enforcement agencies face in balancing long-run encouragement of innovation with short-run concerns about competition.

Networks are a familiar concept to Americans: we are linked to each other by telephone networks, we increasingly shop and obtain information through the web of linked computers we call the Internet, and we confidently slide a card issued by one bank into an automatic teller machine owned by another. The distinguishing characteristic of network goods is that their value to each consumer increases the more they are used by others. New telephone subscribers add to the number of people that existing subscribers can call; their participation in the network increases the system's value to current and future users. New buyers of a word processing package are more people with whom earlier purchasers can easily exchange documents. This additional value that new users add to network goods is termed a "network externality."

Network benefits are not limited to communications systems or to systems in which communication is an element. A good whose usefulness depends on the existence of complementary products—products used in conjunction with the original good—may likewise increase in value to users as more and more people adopt it. A widely used product may attract greater investment in the provision of complements than one that has few users. In the personal computer industry, for example, software producers typically devote most of their efforts to writing programs that will be compatible with the more widely used hardware platforms and operating systems. (Achieving compatibility sometimes requires reverse engineering of existing products; see Box 5-4). Over time more, better, and cheaper software thus becomes available for more popular machines than for others. Similarly, the best-selling video game platform will attract more game developers, thus reinforcing the advantage of that platform over competitors.

Because of network externalities, a product's popularity can be self-reinforcing: new customers buy the more popular good because of the larger externality, which then grows still further, making the product yet more attractive to additional purchasers. This dynamic sometimes makes network markets "tip" toward monopoly. A network monopoly has benefits for consumers not generally found in conventional markets, because its dominance can maximize the network externality. But network dominance also poses hazards that compound conventional economic concerns about monopoly.

First, the product that becomes the network standard will not necessarily be the most capable, most efficient, or highest-quality product on the market. Because consumers want the good that will offer the largest network externality, expectations about a product's success can be at least as important to their purchase decisions as price and quality. Consumers using products, even superior products, that have lost the competitive battle receive a much smaller network benefit, and may eventually have to incur the costs of switching to the dominant product. These include not only the cost of purchasing the rival product but the cost of learning to use it. By the same token, if an inferior good gets a decisive lead in "installed base" among consumers, their switching costs may be enough to keep them from moving to the superior standard. And new customers may find that the greater network externality available from the leader offsets the price or design advantages of the contender.

Box 5-4.—Reverse Engineering and Compatibility

When competing network products are mutually compatible, consumers benefit from the same network externality regardless of which product they choose. If the value of a word processing package depends on the number of people with whom documents can be shared, then a new entrant can overcome its network disadvantage by enabling its product to exchange files with the leading program. Similarly, if a new game platform can play cartridges designed for rival systems, it gains value from the increased availability of complementary goods. Translation between systems is not always perfect, however, and a dominant firm facing new rivals might try to reestablish its advantage by reintroducing incompatibility in subsequent versions of its software. Nevertheless, cross-compatibility remains an important competitive strategy for entrants into network markets—and is beneficial for consumers.

To achieve compatibility, a competitor may have to "reverse engineer" the rival's product, to learn how to make it work together with its own. For that reason, firms with a market edge might try to protect their products against efforts to establish cross-compatibility by restricting competitors' access to critical interfaces where information is exchanged. One means of doing so is to enforce a copyright on the particular lines of computer code that a rival would have to use to make its product compatible. Courts, however, have been increasingly reluctant to uphold copyright protection for such purely functional aspects of computer programs. A leading producer may instead try to encrypt or otherwise technologically protect the information to which a rival seeking compatibility needs access. The Digital Millennium Copyright Act of 1998 expressly permits software developers to circumvent such protections. It thereby limits the extent to which a program copyright can block competition by noninfringing programs or in markets for complementary software. But to avoid undermining the incentive to develop new software, the act allows circumvention only to the extent necessary to achieve compatibility.

Second, these same switching costs can make network markets particularly hard for new competitors to enter, especially if new products cannot interconnect with those already in the market. This potentially makes network monopolies quite stable and reduces the dominant firm's incentives to introduce innovative products and services. An example is the delay in the marketing of digital subscriber line (DSL) technology for high-speed telecommunications. Although DSL technology has been available since the 1980s, only recently did local telephone companies begin to offer DSL service to businesses and consumers seeking low-cost options for high-speed telecommunications. The incumbents' decision finally to offer DSL service followed closely the emergence of competitive pressure from cable television networks delivering similar high-speed services, and the entry of new direct competitors attempting to use the local-competition provisions of the Telecommunications Act of 1996 to provide DSL over the incumbents' facilities.

Third, a network monopolist may have advantages in selling complementary goods that allow it to extend its dominance from one market to another. Advantages in complementary markets are not necessarily anticompetitive. The provider of one good may be able to exploit economies of scale and scope that make it a superior provider of the complementary good. But a monopoly provider of one product may also be able to tie or bundle a second product in a way that forecloses competition in the second product market. For example, it may condition sale of the monopoly good on whether the buyer also purchases the complementary good.

The Challenge for Antitrust

In network markets as in others, antitrust law does not condemn monopolies legitimately achieved. Incentives to innovate and compete might diminish if dominance itself, honestly earned, could be second-guessed by enforcement authorities. Instead, what antitrust proscribes is anticompetitive conduct—predatory or exclusionary practices—that creates or maintains monopoly power. The particular challenge of network markets is that, because network effects can accrue rapidly and be costly to reverse, there is a premium on being able to identify and stop anticompetitive activity quickly. Once dominance is acquired, it may be impractical or undesirable to use regulatory or antitrust remedies to undo the outcome, even if an inferior standard prevails or if anticompetitive tactics have been employed. To be sure, antitrust can target unlawful conduct designed to preserve or extend those outcomes. But once customers have adopted a standard, remedies that would reduce the accrued network externality are costly, no matter how dominance was achieved.

Identifying predatory or exclusionary practices early can be difficult in the network context. Competitive strategies that would be inherently suspect in a conventional goods market may be reasonable in network markets, especially when competitors believe, rightly or wrongly, that the winner will take all. For example, pricing below cost is often a telltale sign of predation in conventional markets. But in network markets it may be a matter of competitive necessity to price below cost in order to penetrate the market quickly, gain a lead in installed base, and raise expectations that a product will deliver a large network benefit. Predatory pricing rules in Federal antitrust policy do allow for transitional circumstances and recognize that prices may not reflect startup costs for new entrants. In applying those rules in network markets, authorities must analyze, on the facts of each case, when aggressive pricing constitutes a legitimate strategy that other competitors would rationally pursue, and when they amount to predatory conduct that forecloses competition.

Similarly, when a network monopolist enters a market for complementary products on terms that make it hard for competitors to succeed, authorities must determine whether the monopolist's advantage stems from genuine efficiencies or from anticompetitive arrangements. Where efficiencies are identified that cannot be achieved in a manner that has less effect on competition, enforcement agencies must balance the welfare gains from those efficiencies against the welfare losses from reduced competition. A good illustration of the problem comes from the days before personal computing. Technological innovations adopted in the 1970s made mainframe computer components sufficiently compact that certain memory devices were for the first time built into the main computer cabinet and hardwired into the central processing unit. IBM Corp., the market leader, thus began to sell computers and memory storage as an integrated unit. Independent manufacturers of IBM-compatible memory devices sued, claiming IBM had leveraged its market power in mainframe computer processors into the more competitive peripherals market. In *California Computer Products v. IBM*, decided in 1979, the U.S. Court of Appeals ruled in IBM's favor after finding on the facts that, in this particular case, integration was an efficient and natural result of beneficial product innovation.

Several very recent enforcement actions demonstrate the complex issues at stake in network competition and show how preserving both the incentive and the opportunity for development of innovative products and services has become an essential concern of competition policy. Among these are actions in the credit card industry and in the markets for Internet software and services.

Credit Cards

As use and acceptance of a particular brand of credit card grow, that card becomes more valuable for both businesses and consumers. This gives rise to a classic network externality, with all the benefits to consumers—and the possible effects on competition and innovation—already described. Concern over competition and innovation among general-purpose credit card networks recently prompted the Department of Justice to file an antitrust suit against the two largest networks, Visa and MasterCard.

The credit card industry operates at two distinct levels. Consumers and merchants are most directly involved in the downstream level, which encompasses card issuance and card acceptance services. The players at that level are banks and other institutions that issue cards and compete for customers on the basis of interest rates, annual fees, payment terms, customer service, and various enhancements or usage bonuses. The Justice Department's challenge concerns the industry's second level: the upstream level, encompassing the underlying card networks themselves. These networks provide various services to card issuers: they implement systems and technologies for card use and clearance, develop card products, and promote the card brand. They also set fees for participation in the card network.

The competitive dynamics of these two levels are very different. If numerous institutions can join a network and issue cards, competition at the downstream level—for consumers of card services and merchants requiring acceptance services—will be strong. Competing at the network level, however, is more difficult. Establishing brand name recognition, developing processing and information systems, and building a sufficient base of merchants and card users take enormous amounts of time and money. Either a new entrant at the network level must attract potential issuers from more established systems, or it must enter the market at both levels itself, issuing cards and providing acceptance services as well as providing network services. The difficulty of the undertaking can be surmised from the fact that only one new network, Discover (now Novus), has successfully entered the general-purpose credit card market in the last 30 years.

Visa and MasterCard began as separate, competing networks owned and governed by their card-issuing members. Each eventually accepted the other's members into its network as participating owners. As a result, the two networks now have substantially overlapping ownership and governance. The Justice Department's case focuses primarily on the innovation-reducing consequences of this arrangement. The Department alleges that the corporate governors have stopped both networks from introducing new products and services because improvements in one network, although they would benefit consumers, would largely shift profits from the other network rather than raise overall returns. And with a combined 75 percent share of the credit card market by volume of transactions, the governors face little pressure from competitors to implement new initiatives in the systems jointly.

The Justice Department's complaint specifically identifies innovations that it alleges were delayed by the two networks' overlapping structure. One of these is "smart card" technology: the use of integrated circuits in the cards themselves to store more data, perform a greater array of functions, and better monitor fraud and credit risk. According to the Department, when Visa indicated that it did not want to introduce smart cards, MasterCard's board decided not to continue their development. Whether the decision was anticompetitive or driven by legitimate business judgment about the commercial viability of smart card technology remains to be proved. But whatever the outcome, the

Justice Department's challenge represents an important application of antitrust policy to the particular problems of competition and innovation in network industries.

Telecommunications and the Internet

Network effects have been essential to the structure and regulation of telecommunications. At the beginning of this century communities were often served by competing telephone systems, with AT&T and an alliance of independent companies each taking about half the market. Generally, the competing systems refused to interconnect with each other and exchange traffic, and so a customer could only call people who subscribed to the same network. Eventually, AT&T was able to tip the market in its favor by patenting superior long-distance technology to which subscribers of competing telephone companies were denied access. This gave consumers an incentive to switch to AT&T, and the company grew into a nationwide monopoly.

In 1984 the Federal Government broke up AT&T's integrated monopoly into a long-distance company and seven regional companies providing local telephone service. Each of these seven companies still had a monopoly over the local service network in its region. The Telecommunications Act of 1996, however, opened the door to local telephone competition by requiring the regional monopolies to, among other things, interconnect and exchange traffic with new entrants into the market on nondiscriminatory terms. From the standpoint of network economics, this provision makes entry easier by allowing any new telephone company, no matter how small, to offer consumers the same network benefit as a larger carrier.

Preserving competition has also been a regulatory priority in telecommunications networks other than the telephone system. Internet "backbone" providers transport information between the high-capacity computer networks that make up the Internet. They sell their services to businesses, institutions, and the Internet service providers (ISPs) that offer Internet access directly to consumers. They also negotiate terms for the exchange of traffic with each other to provide the universal connectivity that defines the Internet. When MCI Communications Corp. and WorldCom, Inc., which in addition to their other lines of business were two leading backbone service providers, were merging in 1998, the Justice Department required MCI to divest its Internet backbone business to an independent competitor. Without the divestiture, the merged company would have had substantial control over the transport of Internet traffic, making it more tempting to reduce the services it provided to rival networks with which it exchanged traffic. The Department's enforcement action thus helped preserve competition in the backbone market and ensure that no single company could dominate the "network of networks" that comprises the Internet.

In another part of the Internet market, the Justice Department has challenged what it alleges are anticompetitive practices in the market for browsers, software that consumers use to access the Internet from their computers. All computers have operating systems that control and allocate the hardware resources of the computer and allow it to run various applications programs of the user's choosing, such as word processors and browsers. The necessity for any new operating system to be accompanied by a range of compatible applications creates a barrier to entry into the operating system market. Operating systems are subject to network effects because more programs will be developed to run on the more widely used systems. As more programs are developed to run on a particular operating system, that system becomes yet more popular to consumers. The result is a market for operating systems that has a propensity to tip to a dominant provider. Currently, Microsoft Corp.'s Windows operating system dominates the market for systems that run on IBM-compatible personal computers.

The Justice Department claims, among other charges, that Microsoft has misused its dominance in the market for personal computer operating systems to maintain power in that market and to attempt to gain dominance in the complementary market for browsers. Microsoft, which packages its browser with current versions of Windows, has allegedly required computer manufacturers to agree, as a condition for receiving licenses to install Windows on their products, not to remove Microsoft's browser or to allow the more prominent display of a rival browser. Because consumers demand that manufacturers preload Windows onto new personal computers, manufacturers face heavy costs if they do not accept Microsoft's terms. Similarly, the Department claims that Microsoft has refused to display the icons of ISPs on the main Windows screen or list them in its ISP referral service unless the ISPs agree, in turn, to withhold information about non-Microsoft browsers to their subscribers. The ISPs are also required, the Department alleges, to adopt proprietary standards that make their services work better in conjunction with Microsoft's browser than with others. Microsoft responds that integrating its Internet browser makes its operating system more functional and increases the features and uses of programs written for that operating system, to the ultimate benefit of consumers. The company also claims that the contractual arrangements with ISPs are nothing more than cross-promotional agreements, which are common within the computer industry.

The case against Microsoft reflects an effort by the Justice Department to prevent perpetuation of monopoly by allegedly anticompetitive means, to protect competition in the Internet browser market and to maintain incentives for the development of innovative software by preventing anticompetitive actions against successful products. The challenge for competition policymakers in this context is to preserve competitive opportunities without punishing successful competitors.

At issue is where to draw the line. Is a successful company's use of aggressive tactics legitimate, so that regulation might reduce future innovation incentives and consumer welfare? Or do those tactics cross the line into misuse of market position to engage in predatory or exclusionary conduct that forecloses competition and innovation, to the ultimate detriment of consumers? Striking the right balance is essential for promoting innovation and protecting consumer welfare in the fast-moving conditions of network competition.

ENVIRONMENTAL REGULATION AND INNOVATION

Environmental regulation addresses the problem of environmental damage caused by pollution generated as a consequence of economic activity. As long as polluters do not bear the full cost of the environmental damage they impose on others, they will lack the incentive to reduce emissions adequately. Unregulated markets therefore typically generate too much pollution. Well-designed environmental regulation can reduce pollution and increase the net value of economic activity, which is the value of goods and services produced after deducting all costs of production, including the social costs of environmental damage.

Environmental policy may have a significant impact on the pace and direction of innovation, which over the longer term may be of greater importance than the impact of policy on immediate environmental outcomes. In what follows, the interaction of environmental regulation and innovation is examined. The incentive to generate new technologies under alternative forms of environmental regulation is discussed. This is followed by a discussion of the diffusion of existing technology among potential adopters and the role for policy to modify diffusion rates. Some of the major points of this discussion are illustrated in the context of policy regarding global climate change. Finally, the long-run impact of environmental regulation on productivity is discussed.

ENVIRONMENTAL POLICY AND INCENTIVES TO INNOVATE

Three Approaches to Environmental Regulation

Governments can implement environmental regulation in any of three principal ways: by providing producers and consumers with economic incentives to reduce their emissions, by enforcing limits on the rate of pollution discharge, or by mandating technology that producers or consumers must use to reduce pollution. This Administration's environmental policy has increased the use of incentive-based approaches. The preference for such approaches is often justified on static cost-effectiveness grounds: an incentive-based approach can achieve any environmental goal at lowest cost, given existing technology, because it induces emitters to reduce emissions as efficiently as they can with the technology at hand. But incentive-based approaches can also be justified on dynamic grounds: under incentive-based regulation, sources of emissions may be more inclined to develop new technology that reduces pollution at lower cost than under alternative forms of regulation. In this way, market forces ensure that innovation and creativity are used to help improve the environment rather than devoted to finding ways to escape the brunt of regulation.

Examples of incentive-based approaches include tradable permit systems, emissions taxes, subsidies to reduce pollution, and liability rules. Under a tradable permit system, the government issues permits that allow emission of a given quantity of a pollutant; total emissions are limited by the number of permits issued. Emissions without a permit are banned. Although total emissions are thus capped, each source of emissions can choose its own level of emissions by buying or selling permits. The added flexibility afforded by permit trading allows sources that find abatement expensive to buy permits from sources that can abate at less cost. Thus, overall emissions are reduced at lower total cost. In 1998, for example, the Environmental Protection Agency (EPA) introduced regulations to reduce nitrogen oxides (NO_X) emissions in 22 States and the District of Columbia, allowing for emissions trading among electric utilities that are sources of NO_X emissions. Sources needing more permits than have been allocated to them can buy them from sources that succeed in reducing emissions below their initial allocation.

Under an emissions tax, sources of emissions are taxed on their activities that cause environmental damage. If the tax is set to approximate the social cost of the environmental damage caused by the activity, sources face appropriate incentives to reduce emissions to an economically efficient level, that is, the level at which the social benefits deriving from additional pollution reductions just cover their cost. Despite the theoretical appeal of emissions taxes, however, they have rarely been used to regulate pollution in the United States.

Subsidies, on the other hand, have been used occasionally to encourage the use of more environmentally benign technologies. A system of environmental subsidies mirrors that of an emissions tax: sources of potential environmental benefits receive government payments to encourage their beneficial activities. For example, under the Energy Policy Act of 1992, electricity produced from wind and biomass fuels—two environmentally benign sources of energy—receives a tax credit of 1.5 cents per kilowatt-hour generated.

Finally, liability rules impose financial responsibility on emissions sources for any environmental damage they cause, thus providing them with a direct incentive to reduce the adverse environmental impacts of their activities. For example, the Oil Pollution Act of 1990 makes firms liable for cleanup costs, natural resource damages, and third-party damages caused by their oil spills into surface waters.

Similarly, the Clean Water Act makes parties liable for the costs of cleaning up their spills of hazardous substances.

As noted at the outset, an economic advantage of incentive-based approaches is their static cost-effectiveness: given existing technology, they achieve a given environmental objective at lower cost. For example, a system of tradable permits minimizes the cost of a given amount of emissions reduction by ensuring that the reduction is undertaken by those emissions sources, and only those sources, that can do it most cheaply. This comes about because any source that can lower emissions at a cost below the market price of permits will profit by doing so, through the sale of its unneeded permits in the market. Likewise, any source for which the cost of reduction exceeds the market permit price will find it profitable to pollute beyond its allowance, covering its excess emissions by buying additional permits in the market.

It is not always feasible to monitor the contribution of individual sources to environmental damage. In such cases it is impractical to allocate emissions permits, levy taxes on emissions, or assign liability for damage. Instead, incentive-based environmental regulation may take the form of providing incentives for emissions sources to change their production methods, rather than incentives to reduce pollution per se. For example, fertilizer runoff from farmland causes nitrate pollution of ground and surface waters, but it is difficult to measure the pollution attributable to each of the many widely scattered ("non-point source") producers. In part because farmers contribute to non-point source pollution, the Department of Agriculture pays up to 75 percent of the costs of certain conservation practices that reduce environmental damage, under the Environmental Quality Incentives Program of 1996.

In contrast to incentive-based approaches, technology standards stipulate the equipment and methods that sources must employ to control emissions. Performance standards, on the other hand, specify a limit on the emissions allowed by each source but allow the source to choose how best to meet this limit. Many environmental regulations combine elements of both performance and technology standards. For example, the Clean Water Act requires sources to meet an effluent performance standard for conventional pollutants that is set according to what could be achieved using the "best conventional technology." Often this becomes a de facto technology standard. Conversely, technology standards sometimes allow sources to use technologies other than those specified if they can demonstrate that the alternative technology will achieve the same amount of pollution reduction.

In the context of environmental regulation, technology or performance standards, in contrast to incentive-based approaches, may not be cost-effective, because they provide no mechanism for concentrating emissions reductions where they are cheapest. Of the two types of standards, performance standards are preferred because they allow emissions sources the flexibility to choose lower cost methods of abatement. Technology standards may also lock in the use of pollution control technologies that are unnecessarily costly in the face of changing conditions.

Incentives to Innovate Under the Three Approaches

Although incentive-based regulation may thus be preferable to regulation by performance or technology standards from the perspective of the short-term, static cost of achieving given environmental objectives, evaluation of the relative cost-effectiveness of the three approaches over longer horizons is more complex. Achieving ambitious environmental goals in a growing economy will require advances in technology (Box 5-5). The evolution of pollution control costs over time is affected by innovation, and the three approaches differ in the incentives they offer potential innovators. Innovation may be particularly important when environmental regulation is relatively new, because then there are often unexplored avenues of research and significant learning-by-doing effects.

An important criticism of technology standards is that they may provide little incentive to search for more cost-effective ways to reduce emissions. A technology standard provides an incentive to develop cheaper new technologies only if those technologies can meet mandated targets and win regulatory approval. Performance standards, in contrast, provide an incentive to find lower cost ways of reducing emissions, at least to the level of the standard. However, they may give little incentive to search for new methods to reduce emissions *below* the

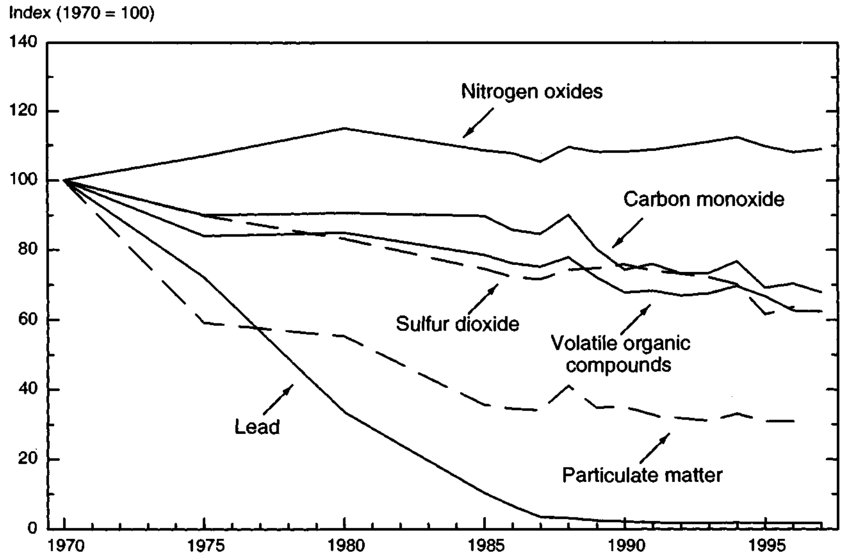
Box 5-5.—Recent Trends in Air Quality

Environmental regulation has sharply reduced emissions of a number of important pollutants over the past several decades. Emissions of five of six major air pollutants (the exception being nitrogen oxides) have fallen substantially since passage of the 1970 Clean Air Act Amendments (Chart 5-1). The EPA's phaseout of lead additives in gasoline has been largely responsible for the spectacular fall in lead emissions since the 1970s: lead emissions in 1997 were less than 2 percent of 1970 emissions.

These improvements occurred during a period of considerable economic growth. From 1970 to 1997, real GDP expanded by 114 percent, so that emissions per unit of GDP have fallen dramatically since 1970. In certain sectors the reduction in pollution per unit of output has been especially striking. Vehicular emissions of volatile organic compounds per mile traveled have fallen by 81 percent, and emissions of carbon monoxide by 73 percent, since 1970. These impressive reductions could not have taken place without substantial innovation in new processes and products as well as their widespread adoption.

Chart 5-1 **Emissions of Six Major Air Pollutants**

Since the Clean Air Act Amendments of 1970, the emissions of five out of six major air pollutants have fallen dramatically.



Source: Environmental Protection Agency.

current standard, unless standards are expected to become tighter in the future.

One way to increase the incentive to innovate under performance standards is for regulators to commit to the implementation of a strict standard in the future. Such strict, "technology-forcing" performance standards raise the value of innovations that lower pollution control costs. Whereas requiring emissions sources to meet a stringent standard immediately with existing technology may impose large costs, announcing the same stringent emissions targets well in advance provides an incentive to innovate, as well as time to develop the infrastructure and make other investments necessary to adopt and implement new technologies. This can reduce compliance costs significantly. For example, in 1970 the California Air Resources Board adopted stringent air emissions standards for new cars, which took effect in 1975. Many at the time did not believe the standard could be met at a reasonable cost. Yet the stringent standard contributed to the development of an emerging technology, the catalytic converter, which cut automobile emissions dramatically and is widely used today. There is a downside, however, to the technology-forcing approach. Innovative activity is risky: investments in R&D may or may not pay off in new discoveries. If they do not, compliance costs may fall by less than anticipated, and the ambitious environmental goal may prove extremely costly to meet. And relaxing the goal at a later date in the face of high compliance costs, thereby rewarding failure, has its own drawbacks.

In contrast to both performance and technology standards, incentive-based approaches reward emissions sources for developing methods that reduce emissions, regardless of their current level. For example, under a system of tradable permits, any technology that reduces emissions allows a source to profit from higher permit sales (or lower permit purchases). Similarly, under emissions taxes, subsidies to reduce pollution, or liability rules, innovations are rewarded through lower costs, higher subsidies, or lower liability payments, respectively. Because incentive-based approaches provide rewards for reducing emissions at all pollution levels, rather than just to a given standard, they offer incentives for innovation that are superior to those under either technology or performance standards.

The Impact of Alternative Regulatory Policies on Reducing Sulfur Dioxide Emissions

Regulation of sulfur dioxide (SO_2) emissions from coal-fired electric generating plants illustrates the importance of environmental regulatory structure for cost savings and innovation. The 1977 Clean Air Act Amendments required new fossil fuel-fired electrical generating plants to remove 90 percent of SO_2 from their smokestack emissions (70 percent if the plants use low-sulfur coal). This policy effectively mandated the use of scrubbers, devices that remove SO_2 from the exhaust gases produced by burning coal.

Title IV of the 1990 Clean Air Act Amendments established a tradable permit program for SO_2 emissions. In phase I of the program, which began in 1995, permits were allocated to 110 electric utility plants around the country. In phase II, which begins in 2000, the program will be extended to cover virtually all fossil-fuel-burning electric generating plants and is ultimately expected to reduce SO_2 emissions to 50 percent of 1980 levels. Under the tradable permit program, plants that can reduce emissions cheaply, by switching to low-sulfur coal, for example, can sell permits to plants for which emissions reduction is more expensive. Estimates of cost savings just from allowing trading range from 25 to 43 percent.

Changing the SO_2 regulatory system to a tradable permit system may also spur innovation that results in additional cost savings. Original compliance cost estimates will be overstated when they do not adequately take technological advances into account. (Box 5-6 explores whether there is a systematic tendency for preimplementation cost estimates to exceed costs actually achieved.)

In fact, estimates of the cost of reducing SO_2 emissions in 2010 have fallen substantially over time. In 1990 the EPA forecast that the total annual compliance cost for SO_2 emissions reduction in 2010 would be in the range of $2.6 billion to $6.1 billion (in 1995 dollars). In contrast, a 1998 study projected annual compliance costs in 2010 at just over $1 billion (again in 1995 dollars). Factors other than technological change

Box 5-6.—Comparing Estimates of Environmental Compliance Costs Before and After Regulation

In part because of the recent experience with SO_2 regulation, some environmentalists have voiced concern that estimates of compliance costs made before regulation is implemented systematically overstate the likely costs. A recent study reviewed the limited number of cases, from 1972 through the early 1990s, where both pre- and postimplementation cost estimates exist, to determine whether the former routinely overestimated compliance costs. The study found both cases of overestimation and cases of underestimation. Prior to 1981, compliance costs for nearly all new regulations were apparently overestimated. Since then, however, the accuracy of estimates has improved and the balance has been more equal.

Preparing accurate estimates of compliance costs involves many challenges. When estimating costs in advance of implementation, analysts must inevitably base their forecasts on the policies actually proposed. But policies are often changed or relaxed in the process of implementation, so that comparison of these early estimates with actual implementation costs often ends up comparing apples and oranges. Furthermore, cost estimates prepared before implementation typically assume 100 percent compliance. But not all firms may comply, and those that do not are often those with the highest compliance costs. Cost estimates after implementation are inevitably based on data covering only those firms in compliance, and hence they tend to be lower than estimates based on perfect compliance. On the other hand, to the extent that cost estimates are not sufficiently optimistic about future technological advances, the costs of compliance will be overstated.

also help explain the dramatic decline in expected compliance costs. For example, certain aspects of the program that effectively loosened the limit on total emissions were not included in the original forecast.

Perhaps the single most important factor, however, was the decline in railroad freight rates as a result of railroad deregulation. Coal from the Powder River Basin in Montana and Wyoming has the lowest production cost and lowest sulfur content of any coal in the United States. Lower railroad rates reduced the cost of transporting low-sulfur Powder River Basin coal to Midwestern utilities. Coal-fired electric generating plants already dependent on coal transported from distant locations gained direct cost savings. Other plants found they could reduce emissions at lower cost by switching to low-sulfur coal rather than investing in scrubbers.

The SO_2 experience reveals several advantages of relying on incentive-based approaches to environmental regulation. First, even with a given technology, allowing trading lowered compliance costs. Second, tradable permits provided added incentives to innovate. Third, tradable permits allowed sources the flexibility to adapt to changing circumstances rather than be locked into a prescribed method. The Administration has recently adopted rules to allow trading of NO_x emissions and is a strong proponent of establishing an effective international permit trading system to meet the reductions in greenhouse gas emissions agreed to in the 1997 Kyoto agreement on climate change.

Getting Innovation Incentives Right

It is widely recognized that the volume of R&D activity undertaken in a market economy may fall short of what would best serve society's interest. The market failures that produce this outcome apply broadly throughout the economy but may be particularly acute in the area of environmental technology.

One critical reason why private R&D activity may be less than what is socially ideal is that the economic and social benefits of a promising new technology may exceed what the innovating firm can capture for itself. This appropriability problem can emerge where patent protection is incomplete, so that rival firms can quickly and freely imitate an innovation, or where basic research leads to advances in knowledge that are difficult to patent. Even where patenting is secure, there are often important knowledge spillovers from one firm to another. Innovations in one field may spawn ideas that lead to innovations in others. Empirical evidence supports the notion of appropriability effects: such evidence strongly indicates that the social rate of return from R&D greatly exceeds the private rate of return. Therefore, a strong case for public support for R&D can be made, to better align the private returns with the social.

Two additional concerns relating to the private provision of R&D are of specific importance to environmental policy. First, environmental regulation itself may aggravate the appropriability problem. As noted above, under technology and performance standards, emissions sources do not receive credit for the value of environmental improvements they introduce. As a result, beyond the usual appropriability problems facing innovators, there may be too little incentive for firms to generate environmental innovations.

Second, inappropriate incentives for innovation may also result when environmental regulation, even when incentive-based, is either too lax or too stringent. When regulation is too lax, emissions sources may have insufficient incentive to innovate to reduce emissions or to lower costs; when it is too strict, they may spend more on devising innovations than the resulting reduction in emissions is worth. Abstracting from the appropriability concerns common to all R&D, incentive-based approaches generate efficient innovation incentives only when they succeed in "getting prices right"—that is, when they ensure that the prices of tradable emissions permits or the taxes levied on emissions fully reflect the actual damages resulting from pollution. Only under these conditions will potential innovators appropriately weigh the cost of innovations against the expected benefits, including both expected reductions in compliance costs and the benefits from reduced pollution.

Thus, although private sector incentives to innovate are typically insufficient, more R&D activity is not always better. Like other investments, investment in R&D activity is justified only when the expected benefits exceed the costs. Of course, it is difficult at the outset to predict the success of an R&D venture, because the returns are inherently uncertain. As Albert Einstein put it, if we knew what we were doing, it wouldn't be research.

Even when regulation succeeds in "pricing" environmental damage appropriately, a strong case can usually be made for government support of environmental research because of the large gap that likely exists between social and private returns, particularly in the area of basic research. The Federal Government funds environmental research to identify environmental threats and find solutions to those threats. Basic research into environmentally friendly technologies can provide the knowledge base for the development of cheaper means of controlling the environmental impact of economic activity. In 1994, direct Federal investment, amounting to $5.1 billion, accounted for around 50 percent of all U.S. environmental R&D expenditures. The greater part of the government's environmental R&D investment is carried out through its system of research laboratories and competitive grants to universities and researchers. Research is also undertaken through public-private research partnerships such as the Partnership for a New Generation of Vehicles (Box 5-7).

ENVIRONMENTAL POLICY AND THE DIFFUSION OF TECHNOLOGY

Although innovation is a necessary precondition for improved environmental technology, better environmental performance will not be realized unless that new technology is adopted. Regulatory, informational, and other hurdles may block or delay the adoption of new, more environmentally friendly technologies. Policy may play a useful role in encouraging the diffusion of new technology if consumers or firms do not adopt new technologies as fully or as rapidly as is best for society.

Box 5-7.—The Partnership for a New Generation of Vehicles

The Federal Government can play a particularly vital role in promoting R&D in situations where the private sector's incentive to pursue innovations with environmental payoffs is distorted. For example, low gasoline prices have made consumers less concerned about fuel efficiency, dampening the automobile industry's interest in developing more-fuel-efficient vehicles. Yet vehicle emissions are a major source of greenhouse gas emissions and other pollutants, and therefore such efforts would produce clear benefits to society.

In response, the Partnership for a New Generation of Vehicles was established in 1993 between the Federal Government and the major domestic automakers, with the aim of dramatically increasing the fuel efficiency of vehicles while maintaining performance and price. A goal of the program is to develop, by about 2004, a production prototype of a midsized sedan that would achieve 80 miles per gallon. The R&D needed to reach that goal ranges from basic research into lightweight materials and alternative power sources to applied engineering of new manufacturing processes. To entice firms to join the research endeavor, the government co-funds both basic and more applied research and provides access to the extensive Federal laboratory system and its experts. To date, several new technologies have been developed that are bringing this goal closer to reality.

Patterns and Incentives in Technological Diffusion

The diffusion of a new technology often follows a well-established pattern. Initially, the new technology is adopted by only a few. Over time the pace of adoption increases, slowly at first and then more rapidly. The pace of adoption finally reaches a peak and then begins to fall as the market approaches saturation. The trendline of cumulative adoption thus follows an S-shaped curve. The spread of information among potential adopters seems to explain this pattern. A few pioneers are the first to become aware of the new technology and make the decision to adopt. Word of the new technology then spreads to those in contact with the pioneers, and each new user informs several others, so that adoptions begin to pick up momentum. Finally, after the bulk of the population of potential adopters has learned about the new technology, the rate of new adoption slows.

This pattern of diffusion provides important insights into the rate of adoption, but it does not answer the policy question of whether that rate is efficient. Failure to adopt technology may be appropriate—the costs of adoption may simply exceed the benefits. But market failures may also impede adoption, even when the benefits outweigh the costs.

For policy purposes it is important to distinguish between these two situations. Only in the second can policy play a constructive role in promoting the adoption of new technology. Like the incentives for innovation, the incentives for adoption of new technologies will be inadequate when market prices fail to reflect the full environmental impact of pollution. For example, if energy prices do not reflect the full environmental consequences of energy use, consumers will have an inadequate incentive to purchase energy-efficient products. An obvious solution to this problem is to "get prices right"—to adjust energy prices so that consumers face the true costs of their decisions.

A different problem arises when potential adopters lack complete information about potentially useful new technologies. In making their decisions about what products to buy, consumers may need to acquire information. As long as consumers both pay all the costs of acquiring information and reap all the benefits of making a more informed decision, their lack of complete information does not constitute a market failure. But in fact they do not reap all the benefits: in the course of adopting a new technology, one person often spreads information about that technology to others, through conversation or by observation. This sharing of information confers a benefit on those who receive it, but because the first adopter does not profit from that benefit, he or she will not account for it in deciding whether to adopt.

If this problem results in too little sharing of information, and therefore too little adoption of worthy new technologies, the solution may be for the government to provide information, or to require others to provide it. The government can also lower the cost of acquiring information by providing a credible source of objective information. The Energy Policy and Conservation Act of 1975, for example, requires many appliances to carry energy labels showing the product's energy efficiency rating and an estimate of its annual energy costs. The EPA and the Department of Energy also operate the Energy Star program, in which products are assessed for their energy efficiency, and efficient products are allowed to display the Energy Star label.

Another approach when consumers lack full information is to regulate technology directly. For example, the Department of Energy has implemented energy-efficiency standards for appliances. This approach may be preferred when providing information is costly.

Residential Energy Conservation: The Energy Paradox

Studies have found that many consumers are unwilling to invest in energy-efficient products such as compact fluorescent light bulbs, improved insulation materials, and energy-efficient appliances, even though they would save money by doing so. Their failure to make these energy-saving and apparently cost-saving investments is sometimes called the "energy paradox."

Consumers' investment in energy efficiency, whether in installing better insulation or buying more energy-efficient appliances, typically involves, like most investments, an initial cost followed by future benefits from lower energy bills. Studies have calculated the rate of return for a variety of investments in energy efficiency and found that these returns often have a present value that exceeds typical financing costs. Thus, consumers could expect net economic savings over time.

One possible explanation for the energy paradox is that many consumers are not in a position to capture the promised savings and therefore have little or no incentive to invest in energy efficiency. For example, renters may not make energy-efficient investments if their rent includes a fixed amount for utility costs, so that they do not directly reap the benefits from conservation. Consumers might also lack information about energy-efficient alternatives. For instance, there is some evidence that providing free information increases adoption rates for energy-efficient lighting. Or consumers may simply be myopic, influenced more by the immediate cash expense than by the promise of future savings. Policies that lower the initial cost of purchase may therefore be the most effective in encouraging adoption.

Some analysts think the energy paradox may be an illusion, an artifact of flawed data or logic. The engineering data used to estimate energy-efficiency gains may be too optimistic: the gains achievable in a laboratory setting may be far greater than what a typical consumer in a typical home would realize. Consumers may fail to install insulation or other energy-saving investments correctly, for example. The costs of investing in energy efficiency may be underestimated as well. The time and resources consumers devote to learning about energy-efficient investments are not usually factored into the analysis. For some consumers, these costs may exceed any possible savings. Energy-efficient products may also have other features or other effects that consumers do not like. Improved insulation may raise indoor air pollution by reducing ventilation; fluorescent light bulbs may not fit existing light fixtures. Finally, given uncertainty about the future price of a new technology, delay may be rational. Even if immediate adoption would save money, consumers who wait may get a better price and thus save even more. Because adoption can take place at any time, analyses that ignore this "option value" of waiting may overstate the value of current adoption.

A conclusive answer to the energy paradox has yet to be found. In any case, recent low energy prices combined with implementation of energy efficiency standards for appliances and various informational programs seem to have reduced the opportunities for investments that save both energy and money.

INNOVATION AND DIFFUSION: AN APPLICATION TO CLIMATE CHANGE POLICY

Climate change is a problem that will be with us for a long time: policies to address the threat will require the abatement of greenhouse gas emissions over decades, even centuries. Given this long horizon, innovation in technologies that can reduce greenhouse gas emissions must play a role, and therefore the impact of climate change regulation on incentives to innovate cannot be ignored. The ultimate cost of global efforts to address this environmental challenge will depend importantly on the pace at which such innovation takes place. The Administration's efforts to deal with climate change therefore incorporate many of the principles discussed above, to create appropriate incentives that promote both innovation and the speedy diffusion of new technology. These efforts are reflected both in achievements in international negotiations and in domestic actions.

Emissions of greenhouse gases, primarily from the burning of fossil fuels and deforestation, have led to a 30 percent increase in the atmospheric concentration of these gases (primarily carbon dioxide, methane, and nitrous oxide) from levels prevailing prior to the industrial revolution. If emissions continue along their projected, "business as usual" path, a doubling of carbon dioxide concentrations from their levels before the industrial revolution is likely midway through the next century. According to the best climate models, this could lead to global warming of the atmosphere of between 1.8 and 6.3 degrees Fahrenheit by 2100. The potential adverse impacts of such a change are many: a rise in sea level, greater frequency of severe weather events, shifts in growing conditions due to changing weather patterns, changes in the availability of fresh water, threats to human health from increased range and incidence of disease, and damage to ecosystems and biodiversity.

To address the risks of climate change, the member countries of the United Nations have participated in a series of international negotiations, including conferences in Rio de Janeiro in 1992, in Kyoto in 1997, and most recently in Buenos Aires in 1998. Building on the 1992 United Nations Framework Convention on Climate Change, the Kyoto climate change agreement places binding limits on emissions of greenhouse gases by the industrial countries over the period from 2008 to 2012. The agreement contains several features that promote the cost-effective reduction of these gases. For example, its proposed emissions trading program grants sources the flexibility to trade emissions allowances with sources in other industrial countries. Further, the agreement provides industrial countries with the flexibility to implement policies that promote trading across different types of greenhouse gases. Sources in industrial countries will have opportunities to invest, through the agreement's Clean Development Mechanism, in clean-energy projects in developing countries, and thereby generate emissions credits for use at home.

The emphasis on emissions trading in the Kyoto agreement embodies the Administration's preference for incentive-based environmental regulation. For the reasons explained above, an incentive-based approach should give firms strong incentives to find low-cost methods of reducing or sequestering greenhouse gas emissions. By pricing greenhouse gas emissions, this approach also stimulates the diffusion of existing technologies and provides private sector incentives for R&D into the next generation of technologies. In addition, announcing emissions targets well in advance may produce payoffs akin to those of a technology-forcing standard. Such an approach provides incentives for firms to innovate, while also allowing them time to adjust by replacing depreciating plants with equipment incorporating new technology, thereby further lowering the cost of emissions reduction. In conjunction with the international trading system proposed under the Kyoto agreement, the Administration supports developing a domestic greenhouse emissions trading program starting in the 2008-12 commitment period. This would allow U.S. firms to participate in international trading of greenhouse gas emissions, as part of an efficient, low-cost national abatement strategy.

Because 82 percent of domestic greenhouse gas emissions come from the burning of fossil fuels, achieving climate change policy goals will require improving the energy efficiency of the economy. The rate of energy efficiency improvement (EEI) across the economy can be thought of as the sum of three factors: market-induced, policy-induced, and autonomous EEI. Market-induced EEI reflects the effect of changes in energy prices on consumption decisions. Policy-induced EEI reflects the effects of policies on energy consumption. The autonomous component of EEI is that which would take place even in the absence of policy and market price changes. The gradual structural shift in the U.S. economy toward services and away from manufacturing and agriculture may explain some of this component. Changes in energy efficiency over recent decades is summarized in Box 5-8.

Policies can provide incentives to invest in energy-efficient technologies and increase the rate of EEI through price changes. For example, the Administration's economic analysis on climate change found that a tradable permit program that results in permit prices of $23 per ton of carbon would increase the annual rate of EEI approximately 25 percent above the level projected in the absence of such a policy.

In addition to policies affecting energy prices directly, the Administration believes that a strong argument can be made for policies to stimulate innovation and diffusion through R&D and appropriate fiscal incentives. The President's 2000 budget includes continued funding for the Climate Change Technology Initiative (CCTI), a program

Box 5-8.—Energy Efficiency Since the 1970s

Energy efficiency in the United States is now much greater than it was at the time of the first oil shock just over 25 years ago. Nevertheless, because of growth in the economy, the United States today consumes more energy than it did in 1973. The ratio of energy use to GDP, a measure of the energy intensity of output, fell rapidly in the 1970s and early 1980s but stopped declining in the late 1980s. More recently it has again begun to decline (Chart 5-2). Yet despite these efficiency gains, total energy use rose by 27 percent between 1973 and 1997 (Chart 5-3), stimulated by population growth and rising GDP per capita. Virtually the entire increase came after 1986, a year that ushered in a period of relatively low energy prices. Before 1986, relatively high energy prices had kept energy use flat.

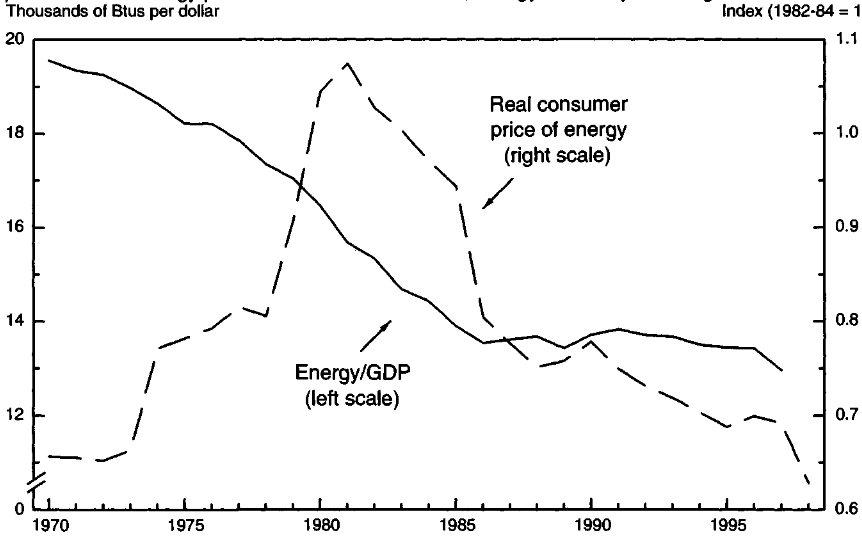
One of the most dramatic increases in energy use has been in that by motor vehicles: their annual fuel consumption rose 54 percent between 1970 and 1996. Although the average fuel efficiency of new passenger cars more than doubled between 1973 and 1996, from 14.2 to 28.5 miles per gallon, the fuel efficiency of the Nation's vehicle fleet has not increased as much, because of a shift toward light-duty trucks and sport-utility vehicles. The efficiency gains were also partly offset by an increase in miles traveled per vehicle and a large increase in the number of vehicles. The net effect of these changes has been a small decline in fuel use per vehicle but a large increase in total energy consumption (Chart 5-4).

Energy use in homes, in contrast, was about the same in the early 1990s as it was in the 1970s, as efficiency gains have kept pace with increases in the number of households, in average house size, and in the average number of appliances per household. For example, the efficiency of the average new refrigerator improved 192 percent from 1972 to 1996. Energy use per household declined rapidly in the late 1970s and early 1980s but has been stable since.

designed to spur the development and adoption of new energy- and carbon-saving technologies through tax incentives and R&D investments. Many of the efforts within the CCTI reflect recommendations made in a 1997 report by the President's Committee of Advisors on Science and Technology. The Committee found that "the inadequacy of current energy R&D is especially acute in relation to the challenge of responding prudently and cost-effectively to the risk of global climatic change from society's greenhouse gas emissions." By providing public support for energy R&D through the CCTI, the level of innovation will likely increase, offsetting in part the appropriability problems associated with this type of R&D.

Chart 5-2 **Energy Efficiency and Prices**

Energy efficiency improved rapidly in the 1970s and early 1980s, periods of rising energy prices. But as energy prices have fallen since then, energy efficiency has stagnated.

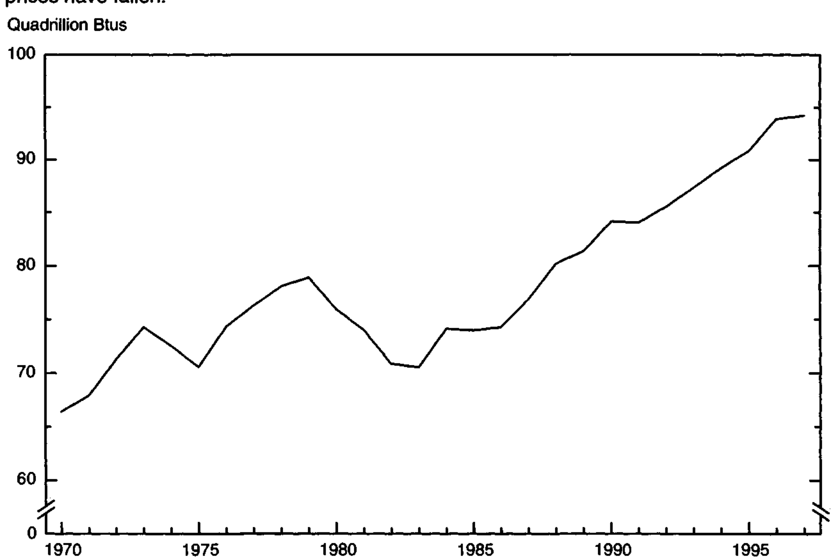


Note: The relative consumer price of energy is the ratio of the CPI for energy to the CPI for all items.

Sources: Energy Information Administration, Department of Commerce (Bureau of Economic Analysis), and Department of Labor (Bureau of Labor Statistics).

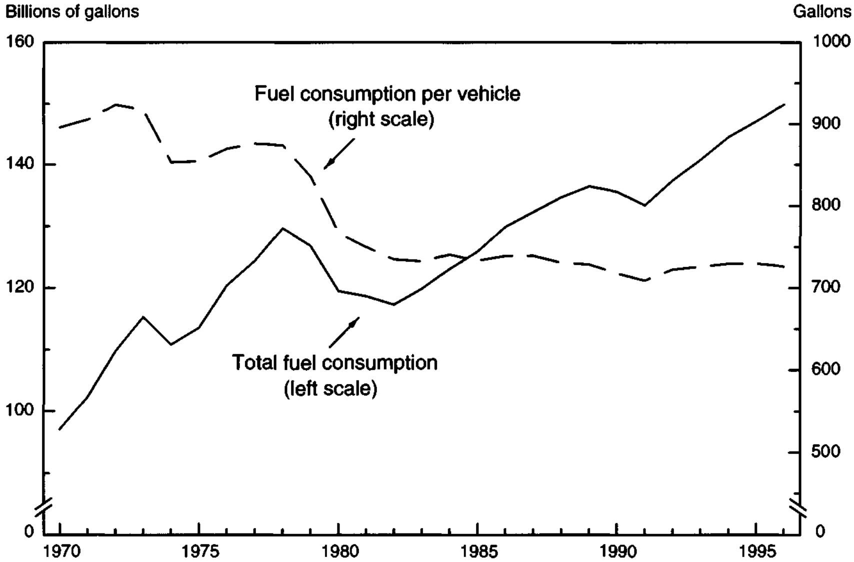
Chart 5-3 **Energy Consumption**

Total energy use has increased significantly since the mid-1980s as energy prices have fallen.



Source: Energy Information Administration.

Chart 5-4 **Fuel Consumption by Motor Vehicles**
Although fuel consumption per vehicle has declined, total fuel consumption by vehicles has continued to increase.



Source: Department of Transportation.

The proposed CCTI package for fiscal 2000 contains $3.6 billion over the 1999-2004 period in tax credits for energy-efficient purchases and renewable energy. These include tax credits of $1,000 to $4,000 for consumers who purchase highly fuel-efficient vehicles, a 15 percent credit (to a maximum of $2,000) for purchases of rooftop solar equipment, a 10 to 20 percent credit (also subject to a cap) for purchases of energy-efficient building equipment, a credit of $1,000 to $2,000 for purchasing energy-efficient new homes, an extension of the wind and biomass tax credit and an expansion of eligible biomass sources, and an investment credit for the purchase of combined heat and power systems. The package also contains $1.4 billion for fiscal 2000 for additional R&D investments covering the four major sources of carbon emissions in the economy—buildings, industry, transportation, and electric power—and investments in carbon removal and sequestration. The proposal builds on the fiscal 1999 budget, which included more than $1 billion in CCTI funding for R&D. The funding in that budget represented a 25 percent increase over fiscal 1998 appropriations for climate change R&D.

Complementing these fiscal measures, the Federal Government can undertake other actions to promote the diffusion of climate-friendly technology. In October 1997 the President called for a series of steps to reduce energy use by Federal buildings, vehicle fleets, and other new equipment, and to promote the use of renewable energy sources. As the Nation's largest single energy user, the Federal Government spends nearly $8 billion each year for power to operate facilities, vehicles, and equipment, and more than 90 percent of this energy comes from fossil fuels. The Federal Government plans to expand its procurement of renewable and less carbon-intensive fuels. These efforts will accelerate the diffusion of new energy-efficient and carbon-lean technologies. Further, the Federal Government's experience with these technologies should speed their diffusion through the rest of the economy, by demonstrating their applicability and feasibility for other users.

THE LONG-RUN COSTS OF ENVIRONMENTAL REGULATION

The policies just described are based on the conviction that the development of new technology, and the widespread adoption and diffusion of already existing technology, can make environmental protection less expensive, and that over the long run it is possible to have both economic growth and a sounder environment. Yet some analysts make a much bolder claim: they argue that further environmental protection can be achieved at little or no economic cost. The energy paradox, described above, perhaps provides some evidence for this claim. If stricter environmental regulation is costless, then implementing such regulation is unambiguously desirable, because it would mean that real environmental benefits can effectively be had for free. Although it is a difficult proposition to test, the weight of the evidence suggests that stricter environmental regulation would impose an additional cost, but a modest one.

There are several ways in which stricter environmental regulation, by conferring benefits on regulated firms and the economy as a whole, might pay for itself. First, environmental regulation might force firms to reconsider their methods of production, which could lead them to discover new methods that simultaneously lower both emissions and cost. For example, in direct response to environmental regulations requiring the phaseout of chlorofluorocarbons, a new method was found for cleaning electronic circuit boards that not only eliminated the use of these chemicals but increased product quality and lowered operating costs as well. Second, firms that become subject to strict environmental regulation before their rivals do may gain a competitive (first-mover) advantage over their competitors by developing new products and technologies for which demand may later become widespread. For example, Scandinavian pulp and paper equipment suppliers increased their exports after more environmentally friendly production processes were introduced in Scandinavia. Third, if there are significant spillover effects from R&D, all firms may benefit from additional R&D activity that comes in response to environmental regulation, even though each firm individually might not have expanded its R&D efforts without the spur from regulation.

Many would dispute the proposition that environmental benefits can be obtained at no net cost. After all, if opportunities for profitable investment are there for the taking, why should firms need prodding by regulators to seize them? Profit-maximizing firms gain by cutting costs and seizing strategic advantages. The profit motive itself should ensure that no large cost savings go unrealized, or first-mover advantages untapped. This critique, however, does not take into account the benefit of additional R&D in the presence of spillover effects. Moreover, difficulties in internal organization may prevent a firm from operating in a manner fully consistent with profit maximization. However, it is not clear that government policies can be designed to overcome these internal organizational problems.

Resolving the debate about whether environmental regulations impose long-run costs will require solid empirical evidence. Although it is difficult to test the proposition directly with existing data, some evidence concerning the long-run productivity consequences of environmental regulation is available. (Some intriguing evidence also exists on the environmental regulatory consequences of increased productivity; see Box 5-9.) The bulk of this evidence indicates that increasing the stringency of environmental regulation does entail a modest reduction in long-run productivity.

REGULATION AND INNOVATION: THE CASE OF THE ELECTRIC POWER INDUSTRY

This chapter has discussed the interplay between regulation and innovation, showing how innovation often necessitates regulatory change, and in turn how regulatory change can affect the pace and direction of innovation. Here we illustrate these themes with a discussion of the ongoing deregulation and restructuring of the electric power industry, one in which technological and organizational innovation has changed the appropriate form of regulation. The electric power industry provides an appropriate case study both because of recent initiatives to introduce competition in electric power generation and because of the potential environmental impacts of power generation.

Although other industries (air travel, trucking, and telecommunications, for example) have been opened to competition over the past few decades, the electric power industry, with sales of $212 billion in 1996, is among the largest yet to be targeted for deregulation. Competition has already been introduced at the wholesale level (electric power generation), but retail electricity markets (the sale of electricity to final consumers) are still, for the most part, regulated monopolies. In 1998 the Administration proposed legislation to remove many of the remaining barriers to competition and encourage States to implement retail competition. The goal of the Administration's Comprehensive Electricity Competition Plan is to provide consumers access to the wholesale power market while maintaining regulation of transmission and

Box 5-9.—Is There an Environmental Kuznets Curve?

We have so far examined the question of whether environmental regulation affects productivity. But could there be an effect in the opposite direction? Some have suggested that higher productivity might lead to increased demand for environmental protection, by way of an increase in income per capita.

In an empirical analysis, the economist Simon Kuznets found that income inequality rose with income per capita at low levels of income, but fell with income per capita at higher levels. The inverted-U relationship thus described has come to be known as the Kuznets curve. Several analyses of patterns of emissions of air and water pollutants across countries have shown a similar relationship to income per capita: emissions seem to increase with income at low incomes, and fall with income at high incomes—an environmental Kuznets curve. If the familiar inverted-U relationship in fact holds in this domain as well (a more recent study, using the latest available data, failed to find it), countries that reach a certain level of development should experience declining pollution with economic growth, because of increased demand for environmental protection with higher income. In other words, growth is not necessarily an enemy of the environment.

Just where the turning point in the relationship between development and environmental quality occurs, if it occurs, is important for predicting whether global emissions of any pollutant are likely to increase or decrease in the near future. If peak pollution levels occur at relatively low levels of income per capita, global emissions should soon begin to fall as more countries pass the peak. However, a substantially higher peak would mean that pollution will likely get worse before it gets better. One study found that sulfur dioxide concentrations peak at income per capita levels around $5,760, roughly that of a middle-income country like Chile. A second study using slightly different data and methods found that emissions per capita of sulfur dioxide, particulate matter, nitrogen oxides, and carbon monoxide peaked at higher income levels.

Unlike air and water pollutants, which have primarily local effects, greenhouse gas emissions seem to increase with income at all income levels. This should not be surprising. Because greenhouse gas emissions contribute to changes in the global atmosphere but do not have visible local effects, national governments, even in the richer countries, come under less pressure from their citizens to regulate their national emissions alone. Without international agreements to limit greenhouse gas emissions, achieving a more prosperous world may entail ever-increasing emissions.

distribution systems, which will probably remain natural monopolies. Just as telephone deregulation has allowed consumers to choose their long-distance company, so deregulation of the electric power industry will soon allow them to choose their source of electricity. The plan has five main objectives: to encourage States to implement retail competition; to protect consumers by promoting competitive markets; to ensure access to and the reliability of the power transmission system; to promote and preserve public benefits (for example, through assistance to low-income customers and consumer education); and to amend existing Federal statutes to clarify Federal and State authority with respect to the industry. The Administration's proposed deregulation plan provides an excellent example of how an enlightened regulatory approach can remove barriers to private innovation, resulting in both economic and environmental benefits. The competitive incentive to produce electricity more efficiently is expected to translate into lower fuel consumption and less pollution.

FROM INNOVATION TO DEREGULATION AND COMPETITION

The electric power industry has been regulated since the early 1900s, when States first began to grant electric companies exclusive service areas. Electric utilities were overseen by public utility commissions (PUCs) and guaranteed a "reasonable" rate of return on their investments, provided they set reasonable rates and met various social objectives such as universal access.

Regulation was justified on the grounds that it was less costly to have one electric utility provide service than to have competing utilities. Firms faced enormous startup costs in installing generating units, transmission and distribution lines, and individual connections. Duplication of transmission and distribution networks by competing firms would have caused unnecessary expense. With the support of the privately owned utilities, States restricted competition by granting utilities monopoly status to encourage them to make the necessary investments and avoid wasteful duplication. As demand for electricity grew rapidly, developments in generating technology also supported the notion that electricity supply was a natural monopoly. By the 1970s, coal- and nuclear-fired plants generally needed to be very large, exceeding 500 megawatts capacity, to exploit economies of scale. The capital demands for such a large plant needed to be spread over a large consumer base for the utility to recoup its investment. Since then, technological and organizational innovations in electric power generation have blunted its natural monopoly characteristics and reduced the need to restrain competition in the generation of electricity. Deregulation in the natural gas industry and the increased availability of gas caused gas prices to fall. The cheaper fuel source spurred innovation in electric power generation and made combined-cycle gas turbine plants, which today can be as small as 100 megawatts, competitive with much larger coal plants. In 1994 these technologies contributed to a 35 percent fall in the average size of new fossil-fuel generating plants relative to that of existing plants. These changes mean that large users can threaten to generate their own electricity if their utilities do not offer lower rates. Technologies on the horizon promise further reductions in the efficient size of electricity generation, to the point where even residential users may some day find it economical to generate their own power (Box 5-10).

The development of an interconnected electricity system, and an improved understanding of how to operate generating plants and the transmission grid independently of each other, have made competition feasible. As the market for electric power grew, individual systems began to interconnect, making it physically possible for consumers in one utility's service area to receive electricity from generators in another. To maintain the integrity of the electric power grid, the quantity of electricity supplied must always match the quantity demanded. With quantities demanded fluctuating constantly, the output of generators supplying power to the grid must be closely coordinated. Until recently, this was taken to mean that generation, transmission, and distribution services needed to be jointly owned. Recent technological and institutional innovations, however, such as computerized controls and independent system operators (ISOs), offer ways to coordinate unaffiliated generators and provide fair, open access to transmission lines while maintaining their integrity.

Today the electric power industry is governed by a mix of State and Federal regulation. But a series of Federal actions beginning in 1978 has begun to introduce competition at the wholesale level. The Public Utility Regulatory Policies Act of 1978 (PURPA) first opened the door by requiring public utilities to purchase power from renewable sources and from sources using cogeneration (see Box 5-10). The price of this "qualified power" was determined by State regulators and tended to be greater than the utility's average cost of generation. Although this requirement saddled some utilities with high-cost, long-term contracts, it also demonstrated that generators not owned by the public utility could be integrated into the electric power system, and it helped spur the development of smaller scale generating technologies. The Energy Policy Act of 1992 went further, creating a new class of independent generating companies that could sell power directly to utilities. In April 1996 the Federal Energy Regulatory Commission (FERC) issued Order 888, requiring public utilities to provide access to their transmission lines at reasonable, nondiscriminatory rates.

At the State level, to further these policies and reap the benefits of competition, many utilities are collaborating to create regional or statewide ISOs to manage their transmission grids. ISOs set transmission prices and can contract for network services (to provide backup power, for example). There are currently four ISOs in operation

Box 5-10.—The Trend Toward Decentralized Power Generation

The trend toward smaller, cleaner, and quieter generating plants, combined with certain aspects of the physics of electricity transmission and generation, has led some to claim that the days of centralized electric power are numbered. Generating electricity from a fuel source is never perfectly efficient; some of the energy in the fuel source is inevitably lost in the transformation process. This energy typically takes the form of heat, which can be captured and used in industrial processes, or as space heating if the generator is physically close enough to consumers in need of heat. An electric power plant thus produces two potentially valuable products—electricity and heat—for the price of one. The exploitation of these potential economies is called cogeneration.

Once generated, electricity typically goes through many steps before reaching the end user. It may be transmitted over high-voltage wires for long distances, after which it must be transformed into lower voltage to be distributed, and finally transformed again before being delivered to consumers. On average, some 7.5 percent of the electricity generated is lost through the distribution chain before reaching the end user. On-site electricity generation avoids the greater part of these losses, thus increasing efficiency and lowering costs.

In the past, economies of scale in electricity generation and the nuisance of locating loud and polluting plants near homes and businesses outweighed this incentive for small-scale local generation. This situation has begun to change, however, as very small scale plants are becoming more competitive with large-scale generation, and as plants are becoming quieter and less polluting.

These changes do not necessarily imply the total demise of centralized power. An electric power grid remains an efficient way of allowing generating plants with different production characteristics to serve consumers with different load profiles. For example, electricity demand from many businesses peaks during the day, whereas residential demand is concentrated during the mornings and evenings. If each of these groups generated its own electricity, not only would each need to have its own facilities, but each facility would spend many hours per day with slack capacity. A single large generating plant can supply the same customers with less total generating capacity. Depending on the size of distribution losses and the value of excess heat, it would be wasteful to have two separate plants, one at the office and another one at home, when one plant could service both loads.

around the country, and seven others are in the planning stages. Still others are planning to form power exchanges or pools to help create efficient spot power markets.

States throughout the country are going further, expanding consumer choice by introducing retail competition into electricity markets. Eighteen States have passed legislation or issued regulations toward this end. Many States and utilities across the country have implemented pilot programs, and statewide retail competition is, to various degrees, already being offered in California, Massachusetts, Montana, Pennsylvania, and Rhode Island.

Although States are thus moving forward, several Federal laws and regulations still hamper full competition in retail markets. For example, the Public Utility Holding Company Act of 1935 makes it hard for utilities to cross State lines to compete in each other's markets. PURPA requires public utilities to purchase expensive "qualified power" but would not impose such costs on new competitors. The Administration's electricity competition plan would remove these and other barriers to competition. It would also modernize the institutions that protect the reliability of the electricity supply system, enabling them to function more effectively in emerging competitive markets.

THE BENEFITS OF DEREGULATION

The traditional means of regulating monopolies through rate setting did not provide strong incentives for utilities to improve their efficiency or offer new services—things that would happen naturally in a competitive market. By allowing companies to compete to provide electricity to consumers, deregulation forces companies to search for more efficient means of producing and delivering electricity, as well as new means of providing the energy services desired by customers. In a $212 billion industry, even small efficiency gains from competition can have large benefits.

Above and beyond the direct efficiency gains in the production and delivery of electricity, retail competition can encourage firms to offer new products and find innovative ways to reduce overall energy costs. Time-of-day metering can encourage consumers to shift their purchases away from peak periods and thereby reduce capacity requirements. As already discussed, there appear to be barriers in the markets for energy-efficient products. Utility commissions have therefore stepped in to force public utilities to invest in energy efficiency. In the move toward a competitive industry, utilities are now rethinking such investments. There is no way for a utility to force consumers to keep buying its power once the utility has made an efficiency investment (buying insulation for a consumer's house, for example). New structures will develop in a more competitive market to allow firms to pay for and install energy-efficient equipment in return for a share of the subsequent savings. Restructuring, by making it easier to bundle efficiency services with the provision of electricity, could provide incentives for increased growth of energy service companies (ESCOs). The potential role for ESCOs is illustrated by the experience in California under deregulation, where many supply contracts for commercial and industrial customers include an energy management component.

Competition may also permit customers to express, through their purchases, their preferences for environmentally sound electricity. "Green" power marketers have sprung up in many of the States now offering retail competition and in those with pilot programs. For a premium, these marketers sell electricity that is generated with a greater proportion of renewable sources than the current mix. If enough consumers are willing to pay enough extra for green power, it will provide a profit motive to encourage the future development of such resources.

THE CHALLENGES OF A COMPETITIVE MARKET: ENVIRONMENTAL AND SOCIAL OBJECTIVES

Regulatory changes bring with them a host of challenges, as old ways of meeting various objectives must be rethought. In the past, PUCs had direct oversight over utilities. In some States they sought to include environmental considerations in their approval criteria for new generating assets. This encouraged the construction of generating plants that were less polluting than would have been the case if utilities were allowed to ignore this issue. With competition, however, PUCs lose their ability to influence the composition of electricity supply. If a utility is required to buy more expensive clean energy, its rates will have to reflect the higher costs. With competition, consumers would then be able to buy power from other providers who had lower costs because they were not subject to the same provisions.

In a competitive market, unless these environmental spillovers are internalized through other means (such as existing environmental regulations), the government must step in to pursue them in new ways. For example, as already noted, PURPA requires utilities to buy power from "qualified" clean generators. In support of the same goals, the Administration's proposal includes establishing a tradable renewable portfolio standard to promote more environmentally friendly power production. This approach would require each generator to cover a fraction of its total generation from renewable sources (not including hydroelectric power). If a seller did not generate enough renewable power by itself, it could purchase credits from companies that exceeded their generation requirement.

Similarly, under competition, other social objectives cannot be pursued by placing requirements on only one set of actors—the utilities. Therefore, the Administration's competition plan would establish a "public benefits fund" to support affordable electricity service to low-income customers, invest in energy efficiency measures, and promote other social goals. The fund would be supported by a surcharge on all electric power transmission.

Deregulation relies on the forces of competition to keep prices reasonable for consumers. The benefits of deregulation, therefore, depend on the extent of competition in each market. The Administration's plan enhances FERC's authority to block anticompetitive mergers and to promote competition through divestiture and other means.