CHAPTER 7

Making Markets Work for the Environment

Hulton Getty/Liaison Agency

In 1900, one of the most common environmental problems confronting cities was the accumulation of horse manure on streets, giving offense to sight and smell and posing a public health hazard. Although the automobile eventually solved this problem, it caused others. Economic growth, structural change, and technological change over the past century gave rise to new environmental problems but also provided the income and know-how needed to address them. Innovative efforts to remedy these problems through market-based incentives help achieve environmental goals cost-effectively and provide lessons to guide efforts to solve the world's potentially most significant environmental challenge in the 21st century: global climate change.

Economic growth brings abundant benefits but can also unleash a wide array of environmental problems. Some, like water pollution, air pollution, and soil contamination, are by now long-familiar afflictions; others, like changes in the earth's atmosphere and climate, are of more recent onset. All must be dealt with, or else the very foundation of growth is threatened. Fortunately the same economic growth, structural change, and technological change that gave rise to these problems also provide the income and the know-how needed to address them. An economy that is healthy and thriving is better able to combat environmental ills. The challenge in addressing environmental problems lies in harnessing and channeling the power of markets, so that they both deliver continued economic growth and foster sound environmental practices.

The past century of experience in addressing environmental pollution illustrates that environmental goals must and can be achieved cost-effectively. Innovative efforts to address environmental problems through market-based incentives—such as emissions permit trading and emissions charges—can, when designed appropriately and applied in the appropriate context, achieve these goals at lower cost than other approaches. Poorly designed environmental markets and regulatory schemes, on the other hand, can squander valuable resources in the pursuit of environmental goals. Importantly, lessons learned in one environmental initiative can often be applied to others. In particular, the lessons already learned from addressing pollution in its various local manifestations can guide efforts to solve the world's potentially most significant environmental challenge in the 21st century: global climate change. The global nature of the problem illustrates the need to provide innovative incentives to global markets to address the potential damages.

Environmental Problems Since 1900

The nature of environmental pollution has changed during the past 100 years, reflecting, in large part, technological change and the changing structure of the economy. As fresh innovations allow firms and industries to reallocate their resources to more productive uses, the by-products of their production processes also change.

A Brief History of Environmental Problems

In 1900, one of the most common environmental problems confronting cities was the waste associated with the primary means of transportation, the horse. People traveling short distances usually rode either on horseback or in horse-drawn carriages. In densely populated cities, horse manure covered many streets, not only giving offense to sight and smell but also posing a public health hazard. The automobile eventually solved this problem but brought new ones in its wake.

As the century progressed, new environmental problems caught the public's attention. Before the introduction of filtration in 1889 and chlorination in 1908, outbreaks of typhoid fever from drinking contaminated water were common. Investments in new treatment technologies addressed this concern, and by 1958, 83 percent of the U.S. population had access to filtered or disinfected drinking water. The dust bowl phenomenon of the 1930s illustrated the potential for agriculture to result in serious soil erosion, as the wind carried away significant amounts of topsoil.

After World War II, faster growth and structural change led to a variety of new environmental problems. The Donora, Pennsylvania, "killer smog" of 1948 that took 20 lives demonstrated the seriousness of the public health threat posed by air pollution. The agrochemical revolution greatly increased agricultural yields, but the roughly threefold increase in pesticide tonnage between 1964 and 1982 also raised concerns about the effects of these chemicals on the environment and on human and animal health. One of these was the impact of the pesticide DDT on the bald eagle, as detailed in Rachel Carson's 1962 book *Silent Spring*. A burning river in Cleveland and air pollution so thick that cars drove with headlights on during the day made manifest the growing water and air quality problems of the 1960s.

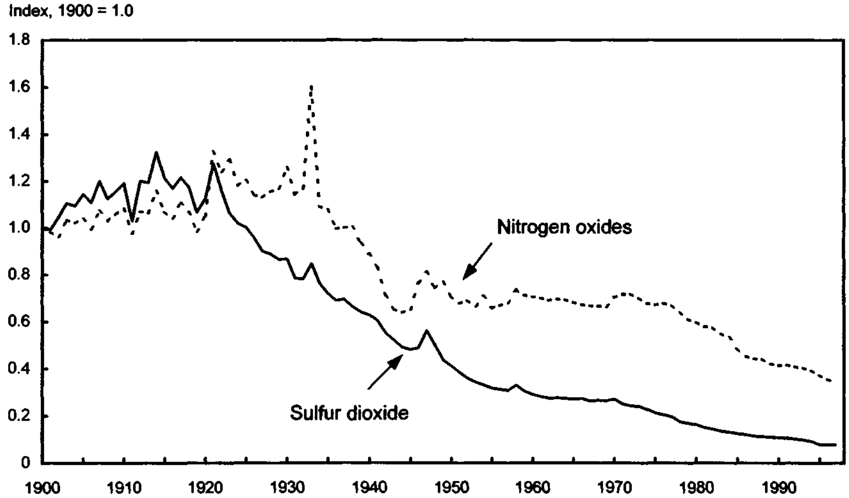
Growing attention to many of these problems culminated in Earth Day in 1970. That event helped spur the series of groundbreaking environmental laws of the 1970s, such as the Clean Air Act, the Clean Water Act, the Endangered Species Act, the Safe Drinking Water Act, and the Resource Conservation and Recovery Act. In the late 1970s, incidents at Love Canal, New York, and elsewhere revealed concerns about the use and disposal of toxic and hazardous substances. The Environmental Protection Agency (EPA) currently has more than 1,200 Superfund sites—areas designated as most contaminated with hazardous wastes—on its national priority list for cleanup and remediation. The hole in the atmosphere's ozone layer that appears each spring over Antarctica, first detected during the 1980s, demonstrates the destructive effect of chlorofluorocarbons on this fragile but critical structure. In the 1990s the scientific community concluded that the balance of scientific evidence suggested that emissions of greenhouse gases from human activity have a discernible influence on the global climate.

Environmental Pollution and Development

This sampler of environmental problems in the United States over the past 100 years mirrors the path of the Nation's economic development. For example, early in the century as the economy developed, emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_X) increased at a faster rate than economic growth. However, in the 1920s and 1930s, emissions relative to gross national product (GNP) began to fall for both of these air pollutants. In 1997 the U.S. economy was only one-third as NO_X-intensive as it had been in 1900 (that is, 1997 NO_X emissions per unit of output were one-third the level of 1900 emissions) and only one-tenth as SO_2-intensive as in 1900 (Chart 7-1). Although these trends may have reflected significant changes in the economy and more effective emissions control since the 1970s, current levels of NO_X and SO_2 emissions still present public health risks in the United States. Much the same has happened with carbon dioxide (Chart 7-2). The continuing transition of the U.S. economy away from traditional energy-intensive industries has reduced

Chart 7-1 **Sulfur Dioxide and Nitrogen Oxide Emissions per Unit of GNP Since 1900**

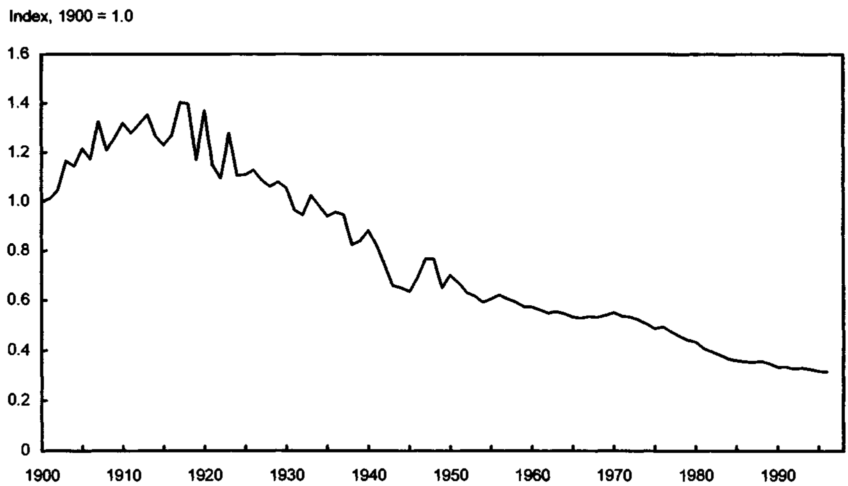
Measured per unit of GNP, emissions of nitrogen oxides in 1997 were roughly one-third, and emissions of sulfur dioxide one-tenth, their levels in 1900.



Sources: Department of Commerce (Bureau of Economic Analysis), Environmental Protection Agency, and Christina D. Romer, "The Prewar Business Cycle Reconsidered: New Estimates of Gross National Product, 1869-1908," *Journal of Political Economy*, 1989.

Chart 7-2 **Carbon Dioxide Emissions per Unit of GNP Since 1900**

Emissions of carbon dioxide per unit of economic output have fallen steadily since the early 1900s.



Sources: Department of Commerce (Bureau of Economic Analysis), Oak Ridge National Laboratory, and Christina D. Romer, "The Prewar Business Cycle Reconsidered: New Estimates of Gross National Product, 1869-1908," *Journal of Political Economy*, 1989.

carbon dioxide emissions per unit of GNP (Box 7-1). Advances in energy technology and changes in primary energy sources may have contributed to this improvement.

Box 7-1. Structural Economic Change and Carbon Dioxide Emissions

Historically, U.S. carbon dioxide (CO_2) emissions from energy use have grown about 2/3 percent for every 1 percent increase in real gross domestic product (GDP). In general, a variety of factors besides growth in aggregate output can affect CO_2 emissions.

Structural change. The U.S. economy continues to experience a shift of its output composition away from traditionally energy-intensive manufacturing sectors.

Weather. Cold winters increase the demand for heating fuels, and hot summers increase the demand for electricity for cooling. Because heating on a cold day is more energy-intensive than cooling on a hot day, on balance a warmer year tends to reduce energy use.

Energy prices. Sharp energy price increases can stimulate energy efficiency and reduce CO_2 emissions, whereas energy price decreases can result in higher energy consumption and higher CO_2 emissions.

Technological change. Technological improvements can reduce the consumption of energy necessary to generate a unit of output. Higher energy prices can accelerate the diffusion of more energy-efficient technologies, as can government programs aimed at promoting energy efficiency.

In 1998, U.S. CO_2 emissions from energy use grew 0.4 percent, while output in non-high-technology industries grew just 2.3 percent—less than the 4.3 percent increase in aggregate GDP and less than the long-term trend rate of growth of 3.1 percent per year for this group of industries. This slow emissions growth probably reflected not only the long-term shift toward high technology and services in the economy but also weakness in several energy-intensive industries, such as chemicals and primary metals. Weather, too, played a role in moderating energy use. The winter months of 1998 were 8 percent warmer than the same months in the previous year. The summer of 1998 was also warmer than the previous year's, but the increase in emissions from more summer cooling was less than the reduction in emissions from less winter heating. Finally, electricity prices changed little, and fossil fuel prices actually fell, between 1997 and 1998.

A statistical model of how structural change, weather conditions, and energy prices influenced U.S. CO_2 emissions over the 1962-98 period found that these emissions track non-high-technology output very closely. After accounting for non-high-technology output, weather,

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Box 7-1.—*continued*

and energy prices, the level of 1998 emissions predicted by the model was very close to (0.5 percent less than) actual 1998 emissions. This suggests that short-term technological change independent of these factors was not an important determinant of the 1998 emissions. As the high-technology component of the economy continues to grow as a share of the total, CO_2 emissions growth should slow further. This would maintain the long-term trend since the 1920s toward a less CO_2-intensive economy (Chart 7-2). As of 1996, for example, the economy was only about one-third as CO_2-intensive as the economy of 1900, possibly reflecting both increased diversity of fuels and change in the composition of GDP. Although it is less CO_2-intensive, growth in U.S. economic output over this century has resulted in a substantial increase in CO_2 emissions.

Many of the same problems are evident today in countries at various earlier stages of their economic development than the United States. The challenge for these countries is to pursue a "cleaner" development path. As they continue to develop and become wealthier, they will have the opportunity to benefit from the experience of the United States and other rich countries in addressing the environmental risks that economic activity generates. In some cases the United States was reactive to environmental problems in the past, because the scientific understanding of various environmental risks, as well as the technologies and policies to address them, lagged the need. Further, the United States lacks a coherent framework for accounting for environmental quality and natural resource use in tandem with market economic activity. A recent National Research Council report, for example, calls for a supplement to the national income and product accounts that would include assets and production activities associated with natural resources and the environment. This information, combined with traditional measures of economic welfare such as gross domestic product, can provide a more complete picture of this Nation's economic development (Box 7-2).

In contrast to the U.S. experience, those technologies and policies are there to be adopted almost off the shelf, and that means developing countries can be proactive, instituting appropriate policies to focus their development along a path that accounts for the costs of pollution. Appropriate policies may allow developing countries to leapfrog the more developed ones in environmental technology, in the way that some already have in communications technology. Just as some countries have adopted fully digitized wireless phone systems without first having built extensive traditional wired systems, so developing countries can effectively skip a generation of more pollution-intensive technologies and

Box 7-2. Taking Account of the Environment

A National Research Council (NRC) report released in July 1999 concluded that extending the U.S. national income and product accounts (NIPAs) to include assets and production activities associated with natural resources and the environment is an essential investment for the Nation. The report argues that it would be even more valuable to develop a comprehensive set of environmental and other nonmarket accounts, although not at the expense of maintaining and improving the current core national accounts.

The NIPAs were designed to measure production and income that arise primarily from the market economy. However, much economic activity takes place outside the market economy. Thus, by omitting important activities such as nonmarket work, environmental services, and investment in human capital, the NIPAs provide an incomplete and potentially misleading picture. Recognizing this, private scholars and governments have begun to develop methods of extending the national accounts to measure as much economic activity as is feasible, whether that activity takes place inside or outside marketplace boundaries. In the United States, the Bureau of Economic Analysis (BEA) began intensive work on environmental accounting in 1992, but it was directed by the Congress in 1994 to suspend further work and seek an external review of environmental accounting. The NRC report represents that review.

The NRC panel argues that environmental and natural resource accounts would provide useful data on resource trends and help governments, businesses, and individuals better plan their economic activities and investments. These accounts would provide valuable information on the interaction between the environment and the economy; they would help in determining whether the Nation is using its stocks of natural resources and environmental assets in a sustainable manner; and they would provide information on the implications of different regulations, taxes, and consumption patterns.

The NRC panel supports developing a broad set of accounts that would parallel each of several asset types. These include subsoil mineral assets such as fossil fuels and metals; renewable and other natural resources such as forests, agricultural resources, and fisheries; and environmental assets such as clean air and water. It is acknowledged that the last category poses considerably greater conceptual and data challenges than the first two. To preserve the integrity of the well-developed core income and product accounts, the NRC panel supports the BEA's preference for developing natural resource and environmental accounts as satellite or supplemental accounts. Satellite accounts serve the basic purpose of the national accounts in

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Box 7-2.—*continued*

providing useful information. In addition, and in light of the current state of knowledge and preliminary nature of the data and methodologies involved, developing satellite accounts allows experimentation and encourages the testing of a wide variety of approaches.

adopt less polluting technologies from the start. Because knowledge and technology developed in one country can diffuse itself worldwide, economic development does not have to result in the same stream of environmental problems that the United States and other industrial countries have suffered since 1900.

Designing Policies to Address Environmental Pollution

Private markets by themselves usually do not provide the needed incentive for producers and consumers to take into account the costs of the environmental pollution they impose on others. For example, a pulp-and-paper mill will aim to minimize all the inputs it must buy in the market, such as labor and capital, in the production of a unit of fiber product. But if it is unregulated, the mill has no economic incentive to minimize its water pollution, because it does not have to pay for the damage that its pollution causes. Absent appropriate policies that provide an incentive for producers to account for pollution costs, economic activity produces too much pollution. Lacking this incentive, the mill also lacks the incentive to invest in research and development (R&D) into pollution-reducing technologies. Well-designed policies that create such an incentive in private markets could make society better off. Of course, an excessively stringent policy might impose a high cost on society, with little benefit at the margin. The costs of eliminating all pollution, for example, could be so exorbitant that society would suffer from having to forgo using those resources on other valuable endeavors, such as education, health care, or product R&D. The task that falls on policymakers, then, is twofold: they must first set acceptable levels of pollution, and they must then select and use policy instruments that will achieve these levels efficiently.

Economists have long argued that environmental goals should be set so that the benefit from the last unit of pollution abatement is equal to the cost of abating that last unit of pollution. However, environmental goals in practice do not usually reflect such an explicit weighting of benefits and costs. Consequently, some environmental policies may have gone too far, imposing costs of pollution reduction that exceeded the benefits and making society worse off. Other policies may have not gone far enough, lowering pollution only to a level where the benefits of more reduction would have still exceeded the costs. In some cases, benefit-cost analysis is legally obstructed from guiding environmental policy, because environmental law prevents regulatory agencies from even considering the costs of reaching the goal. The Clean Air Act of 1970, for example, mandates that air quality standards be set "to protect public health" with an "adequate margin of safety," and the courts have ruled that the EPA Administrator cannot consider the costs of achieving a clean air standard when setting that standard.

Traditional Regulatory Approaches to Address Environmental Pollution

Marked improvements in environmental quality have occurred over the past century, and especially since 1970. These are due in large part to technological innovations that have allowed industrial, energy, and transportation activities to continue while significantly reducing their impact on the environment. Although these gains are important, the means of achieving them have often included inflexible mandates that prescribe specific technologies and result in higher costs than may have been necessary. As the costs of addressing pollution (which the EPA estimated at $125 billion a year in 1990) have increased over the past three decades, attention has come to focus more on the means of achieving environmental goals.

Traditional regulations focused on setting technology and performance standards for pollution sources. (Technology standards mandate specific equipment that sources must use to control emissions. Performance standards, in contrast, mandate a limit on emissions allowed by each source but allow the source to choose how best to comply with the limit.) However, since technology standards mandate the same technologies across all sources, and performance requirements mandate the same level of emissions reductions or emissions rates across sources regardless of any heterogeneity in costs across sources, traditional regulation may not necessarily result in cost-effective attainment of the environmental standard in all areas. Only approaches that focus on eliciting emissions abatement from those activities with the lowest marginal cost of abatement will result in cost-effective attainment of an environmental standard.

Incentive-Based Approaches to Address Environmental Pollution

Two incentive-based approaches to environmental regulation, tradable permit systems and emissions charges, have the potential to save substantial resources in achieving environmental goals, because they promote the cost-effective attainment of emissions reductions. Tradable permit systems apply an aggregate emissions cap or quota to a set of emissions sources. The government then allocates among these sources a number of emissions permits that equals the cap or quota. Allocation may be by auction, or on the basis of the sources' historic emissions or desired performance levels, or by some other approach. Each source must hold enough permits to cover the level of emissions it chooses. Sources can buy and sell permits from each other, and in a well-functioning market an equilibrium permit price will evolve that reflects the value of an additional permit to all sources. Each firm managing a source then faces the same trade-off: it can either cut back emissions by one more unit or buy one more permit. Naturally, firms will cut back on emissions if it is cheaper to do so. The outcome will be that each firm equates its marginal abatement costs to the permit price. And because all sources face the same permit price, marginal abatement costs will be equalized across all sources. This minimizes the costs associated with achieving a given goal. (Box 7-3 provides an illustration.)

The emissions charge approach requires that each emissions source pay a charge based on its level of emissions. Sources will reduce their emissions until the cost of reducing another unit of emissions is greater than the charge. Just as in the case of tradable permits, the marginal cost of abatement is uniform across sources.

Besides promoting cost-effective emissions reduction, tradable permits and charges can promote technological innovation by stimulating R&D investment in a wider range of abatement technologies and processes. When this happens, emissions reductions may ultimately exceed those sought under either technology or performance standards. Under regimes using tradable permits or charges, each firm has the incentive to develop technologies and production processes that reduce emissions regardless of the firm's current emissions level. If, in a tradable permit system, a firm reduces emissions below what its permits allow, it can sell the unused permits to other firms; similarly under a charge system, a firm that reduces emissions pays a lower charge. Under a technology standard, two conditions must be satisfied for a firm to have an incentive to invest in R&D for new, cheaper abatement technologies: it must believe that the cheaper technologies can achieve the same level of emissions performance as existing technologies, and it must win regulatory approval to use the cheaper technologies. Under a performance

Box 7-3. Emissions Trading: An Illustrative Example

Consider a hypothetical example of two neighboring power plants that emit sulfur dioxide. Suppose that both plants emit 100 units of SO_2 each year, so total emissions are 200 units, and a regulatory agency has set an emissions target of 140 units per year for these two sources. Under a traditional approach, the regulatory agency could mandate a known technology (for example, an SO_2 scrubber) that would reduce both plants' emissions to 70 units each. Each plant would need to eliminate 30 units of emissions. Assume that it will cost Utility A \$600 to reduce the 30th unit of emissions, and \$9,000 to reduce all 30 units of emissions, and that it will cost Utility B \$300 to reduce its 30th unit, and \$4,500 to reduce all 30 units. The total cost for both plants of reducing emissions to 140 units per year is thus \$13,500.

However, since the costs of reducing emissions vary significantly between these two plants, a market-based approach can achieve substantial cost savings. If these two plants can engage in emissions trading, they may find it economic for Utility B, with lower emissions abatement costs, to reduce its emissions level below 70 units per year, allowing Utility A to emit more than 70 units per year. Utility B finds that it can reduce its emissions down to 60 units per year, at which point the 40th unit of abatement costs \$400, and the total cost of reducing all 40 units is \$8,000. Utility A can reduce emissions down to a level of 80 units per year, at which point the 20th unit of abatement also costs \$400, and the total cost to reduce all 20 units of emissions is \$4,000. Utility A would save resources by purchasing tradable permits for 10 units of emissions at \$400 a unit from Utility B, because this is less than it would pay if it had to undertake emissions reductions to achieve the 70-unit emissions level. Utility B would earn money by selling 10 tradable permits at \$400 a unit, because this is more than what it costs to reduce emissions. With the sale, the total costs for Utility A are \$8,000: \$4,000 for emissions abatement and \$4,000 for purchasing 10 permits. Total costs for Utility B are \$4,000: \$8,000 for emissions abatement minus \$4,000 from the permit sale. The compliance cost for both facilities with trading would be \$12,000, or 11 percent below the cost with the mandated technology standard (\$13,500).

standard, a firm does have the incentive to find a lower cost way of reducing emissions, but only up to the level of the standard. Some performance standards are so strict that current technologies cannot achieve them. These "technology-forcing" performance standards, when set several years into the future, may induce innovation. However, 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.

These incentive-based approaches also provide an opportunity for the government to raise revenue, either through the auctioning of tradable permits or through the system of charges. Such revenue can be used to reduce existing taxes, thereby delivering additional economic benefits relative to a traditional regulatory approach (Box 7-4).

Important Issues in Designing Incentive-Based Instruments

Environmental problems come in various forms, some of which may be better addressed through emissions trading, others through charges, and still others through other means. By tailoring policy instruments to the characteristics of a given type of environmental pollution and its sources, policymakers can implement policies at lower cost than with traditional approaches.

Uncertainty About Costs and Benefits

The tradable permit approach imposes a fixed quantity restriction on a given type of pollution in the aggregate, whereas a charge approach imposes a specified price on pollution. In a world with perfect information and certainty, these two instruments would have identical effects on emissions abatement and cost. An omniscient regulatory authority could set a charge knowing it would deliver a certain level of emissions, or it could set the quantity of tradable permits in the knowledge that it would deliver a certain price of emissions abatement. In the real world, however, uncertainties about costs and benefits can influence which approach is preferred. For example, if there are paramount concerns about the environmental effects of a control policy, a tradable permit approach may be preferred. This could be the case where a small increase in the level of emissions could result in a large decrease in benefits. On the other hand, if the costs of achieving a given emissions level are highly uncertain, the charge approach may be preferred. This could be the case where estimated abatement costs for a given level of emissions lie in a wide range. If there are concerns about both costs and benefits, a hybrid approach could allow for sources to engage in a tradable permit system but place a ceiling on the permit price (for example, a price at which the government would sell additional permits), to ensure against exorbitant compliance costs that exceed the marginal benefits.

Box 7-4. Should Regulators Allocate or Sell Tradable Permits?

The Administration has proposed a domestic greenhouse gas tradable permit program for 2008-12. Implementing a tradable permit program would require industries covered by the program to restrict their greenhouse gas emissions to comply with the Kyoto Protocol emissions target. Abating greenhouse gas emissions involves costs associated with investing in new technologies, fuel switching, and other means of reducing emissions. As the energy sector becomes more competitive over the next decade, the costs of controlling emissions will be reflected in consumer prices. For example, the Administration's economic analysis of the Kyoto Protocol found that a tradable permit price of $23 per ton of carbon equivalent would increase energy prices to consumers by about 5 percent in 2010.

A key question in implementing a tradable permit system is the distribution of permits. For example, the government can allocate (give away) permits to firms, or it can sell permits to firms through auctions. So long as the tradable permit market is efficient, the price of energy to consumers is likely to be the same in either case. Permits will be scarce, and the price of energy will reflect the cost of buying a permit or taking abatement measures regardless of how the permits were originally distributed. Producers who receive free permits will be like owners of particularly low cost oil wells when oil prices go up: they will sell at the market price and reap windfall profits. In contrast, an auction allows the government to capture the value of the permits, because competition should lead companies to bid away almost the full value of any potential windfall profits from owning the permits.

Allocating permits to firms would result in handing over assets valued in the tens to hundreds of billions of dollars annually. Because these firms can pass on most of the cost of reducing emissions to consumers, allocating permits would provide these firms with significant windfall profits and allow them to enjoy higher profits under climate policy than without climate policy. On the other hand, if the government sells permits, it will receive revenue in the tens to hundreds of billions of dollars annually. Although energy firms would make lower profits under an auction system, the permit revenue could, for example, be recycled back into the economy through tax cuts. Recent research has found that such revenue recycling could reduce the costs to society resulting from the use of greenhouse gas permits by up to about 80 percent.

Allocating permits to energy industries would significantly increase the value of their equity, whereas selling permits would lower it. An alternative is to follow a hybrid approach that combines elements of both allocating and auctioning. Recent research has estimated that allocating

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Box 7-4.—*continued*
roughly 5 to 15 percent of the permits to energy firms while auctioning the rest would be sufficient to ensure that these firms' average equity values would be unchanged, all else equal. Furthermore, since most of the permits would be auctioned, such an approach would still provide significant revenue to the government.

Heterogeneity in Abatement Benefits

The environmental effects of a unit of pollution may vary across sources. For example, rural Montana is in attainment with the national standard for ozone, so the NO_X emissions that contribute to ozone concentrations may not have any significant human health effects. However, Los Angeles is not in attainment with the standard, so NO_X emissions there contribute to ozone concentrations that do cause human health problems. Further, with prevailing wind patterns, NO_X emissions from Montana are not expected to carry to Southern California and contribute to ozone concentration in Los Angeles. Thus a one-for-one emissions trade between a source in Montana and a source in Los Angeles would not be appropriate, and a more complex system that takes account of different environmental effects of emissions in these two areas would have to be designed. The key attribute of an environmental problem, then, that facilitates effective trading is sufficient mixing of emissions prior to human exposure. For example, if two sources near each other emit NO_X, and their emissions mix well in the local airshed, the environmental effects of a unit of emissions by either source can be considered roughly the same. The benefits of emissions abatement will then be roughly the same regardless of which source undertakes the abatement. In this case a simple permit trading program would be appropriate, because it would deliver environmental outcomes comparable to those from a traditional regulatory approach.

Variability in abatement benefits among sources could result in a permit trading program creating "hot spots," or local areas where emissions concentrate to the detriment of public health and the environment. As trading of emissions permits proceeds, a set of neighboring emissions sources might purchase a substantial number of permits and maintain high levels of emissions. Locally high concentrations may not matter for some environmental pollutants, such as carbon dioxide, because of the global nature of greenhouse gas accumulation and mixing. However, some hazardous air pollutants, such as benzene, do have local effects, and the potential for a hot spot could arise with a tradable permit system for such emissions.

Heterogeneity in Abatement Costs

If the cost of abating emissions varies substantially across sources, the potential for cost savings through a trading program is great. It would be profitable for a firm with a high cost of reducing emissions to make a trade with a firm with a low cost, at a price somewhere between the two costs. Large discrepancies in abatement costs—which may relate to differences in the age of facilities, in previous investments in pollution control technologies, in fuel inputs, or in other respects—provide the economic incentive for a high volume of trade and can facilitate the development of an emissions market. However, if the costs of reducing pollution are similar across sources, a tradable permit system might not deliver substantial cost savings. The transactions costs of participating in trading (for example, from having to seek out another firm with which to trade) may overwhelm the cost savings associated with the trade if the two firms have similar abatement costs, and this may reduce the incentive to trade. In such a situation, a charge or other type of regulation may be more appropriate than trading.

Scope of the Emissions Trading Market

The size of a potential emissions market can significantly affect the volume and cost savings of a tradable permit system. A market with a small number of emissions sources may experience low trading volumes and inefficient, monopoly-like behavior—a robust market may never evolve. A larger set of participants can promote a more active, efficient market.

Several factors can influence the number of participants in a tradable permit market. First, the monitoring of emissions sources can significantly influence which sources participate and which do not. If their cost of monitoring emissions exceeds the gains from trading, small firms will have no incentive to join the trading program and will likely prefer a traditional regulatory approach. Continued technological development in monitoring equipment may help reduce the costs of monitoring and allow for markets to expand to more sources. However, inability to effectively monitor some sources may make it more difficult to design well-functioning tradable permit systems and emissions charges.

Second, additional scientific research on the human health effects of various types of emissions can influence the size of a market. By taking advantage of similarities in the effects of different pollutants, tradable permit markets can be structured to allow for trading across pollutants. For example, because both NO_X and volatile organic compounds contribute to the formation of ozone, the potential is there to allow for trading across these gases. However, some of these compounds may also be carcinogenic, so a system of multipollutant trading should also recognize that a given pollutant might have multiple health effects.

Third, the extent of participation in a permit market may also depend on the technical capacity within firms to understand and engage in the trading system. Participating in a tradable permit market requires that a firm first evaluate its own cost of emissions abatement, then assess its potential role as either a buyer or a seller in the permit market, and finally identify potential trading partners and execute the trade. This involves a different set of managerial skills than does the traditional regulatory approach, which tends to require primarily an engineering focus. This may have important implications when considering the application of such instruments in other countries, where firm managers may have less experience both with environmental protection rules and with efficient markets.

Restrictions on Trading

Restrictions on trading eliminate some of the benefits of this approach, and substantial restrictions can seriously hinder the development of an efficient market in emissions permits. Restricting a firm's purchases of tradable permits to a specified fraction of the firm's own abatement raises the costs of achieving a given environmental standard without delivering additional environmental benefits.

Liability

Approaches that result in uncertainty regarding the value of tradable permits also may reduce participation in such markets. For example, a government may restrict the buyer's use of emissions permits and may even revoke them at a later date, depending on an ex post evaluation of the seller's emissions abatement. This increases uncertainty because it effectively institutes a system of buyer liability. If the seller does not undertake emissions abatement sufficient to back the permits it has sold, the sold permits are effectively returned to the seller. Then the seller has sufficient permits to cover its emissions, but the buyer, having effectively surrendered its purchased permits to the seller, does not have enough permits to cover its emissions, and will be found out of compliance. The buyer effectively becomes liable for the seller's efforts to abate emissions. The uncertainty that this buyer liability creates may bias firms against interfirm trading, leading them to focus solely on intrafirm or internal trading, where the benefits are more limited.

Banking and Borrowing

The severity of some environmental problems is a function of the stock of pollution as it accumulates over time, whereas for others it is a function of the flow of pollution during a specific period of time. An example of the first type is carbon dioxide emissions: these accumulate in the atmosphere, where they can last for more than 100 years, and it is their total stock that influences global warming. In contrast, ground-level ozone pollution usually threatens human health most significantly during short episodes of perhaps several days. In the first case, the long-term effects of pollution over time may allow for trading to occur across time as well as across space. With stock pollution problems, a unit of pollution in one period may have environmental effects roughly comparable to a unit of pollution in a subsequent period. With flow pollution problems, emissions in one period may have significantly different environmental effects from emissions in a later period, and this limits intertemporal trading.

The flexibility to trade across time—to effectively bank, or save, emissions permits for future use or to borrow permits from the future for current use—can also result in significant economic benefits. If environmental standards are expected to become more stringent in the future, the costs of emissions may increase significantly over time. Thus a firm may find it profitable to reduce emissions below the standard early in the program and save its surplus emissions permits for use later in the program. However, if the costs of a pollution control program are high in the near term because developing new technologies requires time, it may be profitable for a firm to borrow an emissions permit from the future and use it in the current period. In cases where total emissions over time, not the flow of emissions, cause the environmental damage, this flexibility to trade emissions across time can reduce the costs of achieving a desired environmental goal. Without the opportunity to bank and borrow, permit prices—even in a well-functioning market—could vary significantly over time and could even spike in the presence of new or unexpectedly stringent standards.

Tradable Permits and Charges in Practice

Economists have advocated emissions charges since the 1920s, and tradable permit systems since the 1960s, yet both approaches received limited application until recently. Among the first applications of permit trading were the EPA's efforts in the 1970s to provide additional flexibility to firms as they complied with Clean Air Act regulations. Later applications of trading to air quality issues have included the Regional Clean Air Incentives Market in Southern California, the phaseout of lead additives in gasoline, and the sulfur dioxide trading program. The charge approach has been used to address residential solid waste generation. Although these applications represent only a subset of incentive-based approaches in the United States, they illustrate the importance of appropriate policy design in achieving environmental goals at the lowest possible cost.

Permit Trading: Emissions Trading Policy Under the Clean Air Act

The Clean Air Act of 1970 directed the EPA to develop ambient air quality standards for common air pollutants. Accordingly, the EPA set standards to protect public health for ozone, sulfur dioxide, lead, particulate matter, nitrogen dioxide, and carbon monoxide. It designated metropolitan areas that did not comply with these standards as "nonattainment areas" and established a set of technology and performance standards for a variety of emissions sources. In the late 1970s, to provide some flexibility in reducing emissions, the EPA implemented a trading policy consisting of "netting," "offsets," "bubbles," and "banking" mechanisms.

Netting allowed a facility that created a new source of emissions to net its total emissions across all sources within the facility. This effectively promoted internal "trading" among sources within a facility: the new source could emit pollutants in excess of its required level if an existing source reduced its pollution below its required level. Offsets allowed a new source in a nonattainment area to offset its emissions by paying to reduce emissions at another source in that area. Bubbles created aggregate caps for all existing sources within a facility. Instead of specific technology standards for each smokestack, the facility has the flexibility to reduce emissions in any manner it desires so long as the aggregate emissions are consistent with its cap. In addition, a facility with emissions below its bubble limit could sell emissions credits to other firms. Banking allowed facilities to save emissions reductions that exceeded the current standard for use at a future date. Whereas netting only occurs with respect to internal trading, the other three mechanisms can occur through both internal and external trading.

The experience with these mechanisms showed benefits but also demonstrated some design problems that limited the cost savings. A review of these programs in the late 1980s found that netting generated by far the greatest economic benefits, with estimates ranging rather broadly from $500 million to $12 billion. Bubbles generated cost savings on the order of more than $400 million, and offsets could likewise have generated benefits on the order of several hundred million dollars. Little banking activity occurred, resulting in very modest benefits. Nor was there much external trading: only about 10 percent of offsets occurred between two firms, and fewer than 2 percent of bubbles were between two firms. Compared with estimated Clean Air Act compliance costs on the order of $500 billion over the 1970-90 period, these cost savings are very modest.

Several factors may have dampened the volume of external trading and the subsequent cost savings. First, the ability of firms to engage in trading was restricted. Firms had to invest in abatement technology before they were allowed to purchase permits from other sources, and this effectively stunted the growth of the emissions permit market. Trading ratios greater than one (for example, where one firm sells 12 permits but the buying firm can only use 10 of the permits that it purchases) reduced trading. Second, the review process for trades was costly and created uncertainties about whether the emissions credits created actual property rights; this uncertainty further lowered their value. The uncertainty that buyer liability creates may have biased firms in early trading programs toward internal trades. Third, the concept of trading was novel to many facilities managers, and the lack of appropriate human capital has been suggested as one reason for the low volume of external trading.

Trading under these rules in Southern California during the late 1980s incurred transactions costs as high as 30 percent of the value of the emissions permits in the transaction. These transactions costs reflected the costs of negotiations with other parties, an administrative fee, a certification fee, and costs for documenting the trade and the emissions reduction. If a firm wanted to bank emissions permits, it had to pay a banking fee as well. Moreover, the Southern California regulatory authority granted only 60 percent of proposed trades, and this increased uncertainty among potential participants. Together the extensive fees and the review process dampened the market for emissions permits.

Permit Trading: RECLAIM

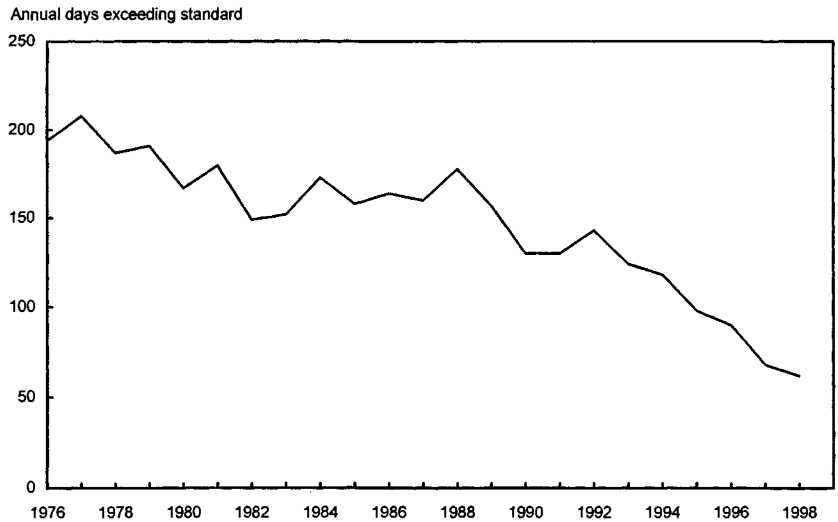
In response to the increasing cost of air quality regulation and the inefficiency of the then-current system of trading rules, in 1994 the Southern California Air Quality Management District began a tradable permit system known as the Regional Clean Air Incentives Market (RECLAIM). This program covers stationary sources that emit 4 or more tons annually of either nitrogen oxides or sulfur oxides. Smaller facilities can join the program voluntarily as well. The program also includes provisions that allow the retirement of older, more-polluting automobiles to generate emissions credits to be used by stationary sources. At its inception the program included 65 percent of all NO_X and 85 percent of all SO_X stationary sources (such as electric utilities and petroleum refineries).

RECLAIM has a single major restriction on trading, designed to prevent hot spots. Geographically, sources are divided into an inland zone and a coastal zone. Trades can occur within a zone, but permits can only be sold from coastal zones (upwind) to inland zones (downwind), not vice versa. Without this restriction, a significant set of upwind sources could emit enough NO_X to result in the ozone standard being exceeded locally downwind.

To facilitate compliance, major sources must install continuous emissions monitors (CEMs), which provide emissions data to the regulatory authority. For 1994 through 1997, CEMs in RECLAIM cost approximately $13 million more per year than the monitoring equipment that would have been required under a traditional regulatory program. This cost was about one fifth the projected cost savings associated with the program between 1994 and 1999 and comprised a majority of the projected compliance costs borne by participating firms. However, monitoring provides important benefits. By providing greater certainty about a source's emissions, monitoring may enhance the integrity of the environmental market and reduce the need for regulatory supervision of every trade. RECLAIM has been largely successful in reducing emissions in a cost-effective manner. Annual ozone standard violations in 1998 were roughly two-thirds fewer than in 1980, and half the number in 1993 (Chart 7-3).

Chart 7-3 **South Coast Air Basin Exceedances of Federal Ozone Standard**

Southern California exceeded the Federal ozone health standard on roughly one-third as many days in 1998 as in 1980 and half as many days as in 1993.



Source: South Coast Air Quality Management District.

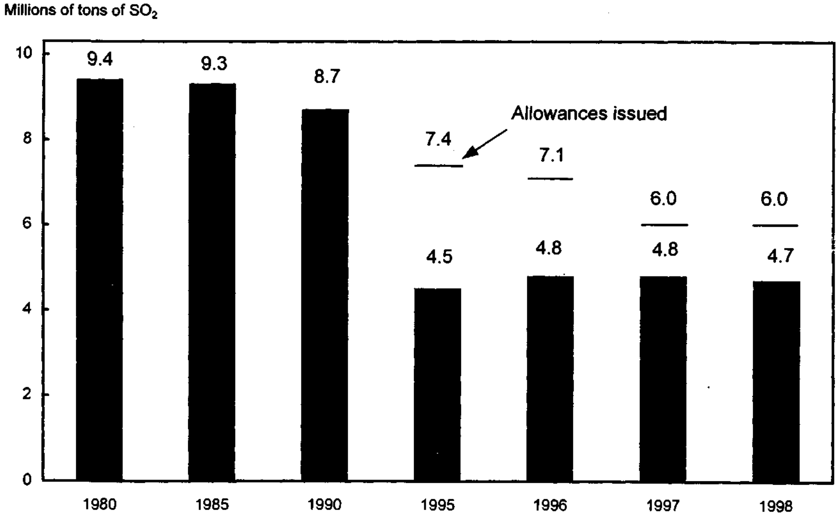
Permit Trading: Sulfur Dioxide Trading Program

In the atmosphere, emissions of SO_2 transform into sulfates and sulfuric acid and are transported over large distances. Because 70 percent of all U.S. SO_2 emissions come from electric utilities, and many of these are based in the eastern half of the United States, the sulfates are usually deposited in the Northeast. Acidic deposition, also known as acid rain, can acidify lakes, resulting in fish kills; it can reduce the alkalinity of forest soils, thereby harming various tree species; and it can degrade various ecosystem functions. In addition, SO_2 has been linked with several respiratory problems.

To address the acid rain problem, the 1990 Clean Air Act Amendments directed the EPA to design a tradable permit system for SO_2. The program required the 110 highest emitting, primarily coal-fired, power plants (representing 263 units) in the Eastern and Midwestern States to hold, starting in 1995 (phase I), permits sufficient to cover all their SO_2 emissions. Starting in 2000 (phase II), all large fossil fuel-fired power plants (approximately 2,000 units) in the eastern half of the United States will have to hold enough SO_2 permits to cover their emissions. Most allocations are based on the product of a common emissions performance standard and historical utilization, although a small percentage every year (about 3 percent) are auctioned at the Chicago Board of Trade. Utilities can freely buy and sell permits, and entities not required to hold permits to cover emissions may also participate in the SO_2 market. Utilities can also bank emissions permits for use in future years.

The SO_2 market has enjoyed very active participation and yielded substantial cost savings. Innovations in scrubber technology as well as the availability, due to rail deregulation, of low-cost, low-sulfur coal from Wyoming and Montana have contributed to compliance estimates as low as half of what had been predicted for the program. The market has experienced high volume, in part thanks to the role of private brokers. Compared with a traditional regulatory alternative, the fully implemented SO_2 market has generated cost savings of up to $1 billion annually. The heterogeneity of abatement costs for SO_2 in the utility industry has been recognized as one reason why the SO_2 market has experienced such heavy volume and substantial cost savings. The absence of individual trade reviews by the government and a system of seller liability have also contributed to high trading volumes. Banking of permits has also occurred to a substantial degree: total SO_2 emissions in 1995 were nearly 40 percent below the environmental goal because of banking activity (Chart 7-4). These banked permits will likely be used during phase II, which has tighter annual emissions limits.

Chart 7-4 **Emissions from Phase I Facilities in the Sulfur Dioxide Trading Program**
SO_2 emissions from the original 263 units have fallen well below binding targets, possibly reflecting the banking of emissions credits by firms in anticipation of stricter phase II limits.



Source: Environmental Protection Agency.

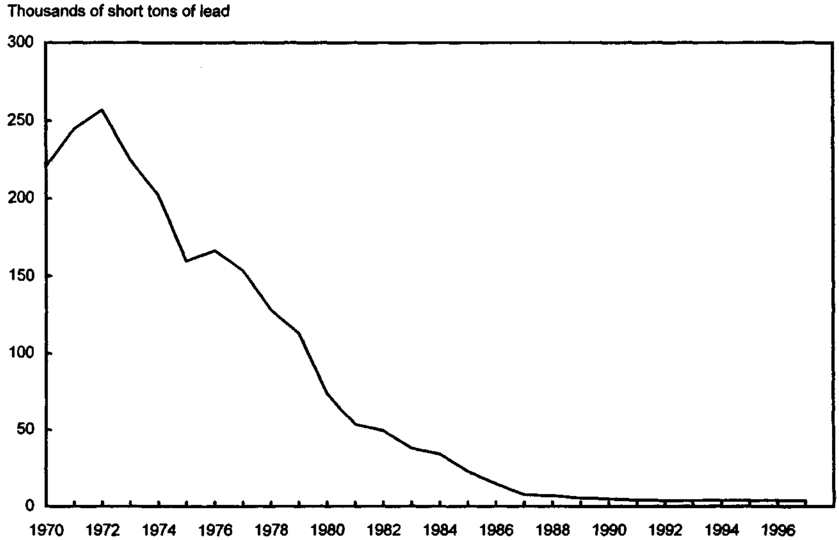
Permit Trading: Phasedown of Leaded Gasoline

Exposure to lead can cause an array of health problems, including a reduction in children's IQ, behavioral disorders, and adult hypertension. Exposure to lead can occur through a variety of pathways, such as ingestion of lead-based paint flecks and lead-contaminated dust, drinking lead-contaminated water, and inhalation of airborne lead resulting from the combustion of lead-based gasoline. In the 1970s, vehicle emissions were responsible for approximately three-fourths of total U.S. lead emissions.

To address the risks of lead exposure, in 1982 the EPA implemented an interrefinery trading program for lead credits. The EPA capped the amount of lead allowed in all gasoline sold, and this cap declined until the lead content was 10 percent of its previous level. To sell gasoline containing lead, a refinery had to hold lead credits commensurate with the lead content of the sold fuel. Refineries could buy and sell lead credits, and the volume of trade was quite substantial.

During 1983 and 1984, only one refinery did not participate in the trading program. Up to 50 percent of all lead in gasoline was at one time or another the object of a lead credit transaction between refineries. In addition, the EPA provided a banking mechanism starting in 1985, and many refineries took advantage of banking until the end of the phasedown program in 1987. The inclusion of banking may have reduced costs up to 20 percent over alternative schemes without banking. Unlike the experience with air pollutant emissions trading in the early 1980s, the phasedown of lead evolved into a fairly efficient market, resulting in an extraordinary reduction in lead emissions (Chart 7-5). Although this certainly reflects the less intrusive government role in the lead market (individual trades did not require government approval), the efficiency of the market may also reflect the technical capacity within firms to participate in trading. Firms that already have experience in trading, such as refineries that engage in intermediate product markets within the refinery industry, may be more inclined to trade. However, smaller firms may have been less inclined to trade because they lacked the technical capacity to evaluate their own costs of removing lead from gasoline and to assess their potential role in the lead market.

Chart 7-5 **Lead Emissions**
Lead emissions have been virtually eliminated in the United States.



Source: Environmental Protection Agency.

Charges: Unit-Based Pricing of Residential Solid Waste

Everyday activities generate solid waste. Through direct and indirect consumption, an average individual generates approximately 4 pounds of waste per day. The generation of waste requires the appropriate disposal at landfills and incinerators. Its disposal can result in numerous problems, including water pollution (from landfills), air pollution (from incinerators), and transportation-related problems associated with hauling waste, including noise, odor, and traffic congestion.

To address the problems associated with waste disposal, many communities have implemented waste management programs that include unit-based pricing of waste collection, in which households pay for disposal services according to the amount of waste they set out for collection or bring to collection centers. This alternative to traditional methods of paying for trash collection (through general revenue or a flat annual fee) can provide explicit information about the cost of waste generation to households. Households can respond in a number of ways to being charged for each unit of waste they set out for disposal. For example, they can do more recycling, set aside yard waste for separate collection, or buy goods with reduced packaging (what is called source reduction behavior). Some people have worried that unit-based pricing could also promote illegal dumping and burning, although this has not been a serious problem in most communities, in part because of antidumping programs. Under unit-based pricing, collection schemes usually take one of three forms: special bags; tags or stickers attached to waste receptacles; or subscription cans of varying sizes. Recycling programs and public education campaigns on viable substitutes for waste disposal often accompany the introduction of unit-based pricing programs.

By 1998, more than 4,000 communities in 46 States had adopted unit-based pricing schemes for their residential waste collection, covering nearly one in seven Americans (Table 7-1). Unit-based pricing reduces the amount of waste collected for disposal relative to a flat-fee system. Increasing the number of types of recyclables covered by a community's recycling program and introducing a yard waste collection program also appear to reduce the amount of waste collected for disposal. However, the total amount of waste

TABLE 7-1.—*Number of Communities Adopting Unit-Based Pricing Residential Solid Waste Collection Programs*

Start date	Cities (number)	Population (millions)	Households (millions)
No information[1]	1,541	8.3	2.2
Pre-1986	130	4.1	1.6
Pre-1991	883	5.1	1.9
Pre-1996	1,404	11.2	4.1
Pre-1999	65	5.7	2.1
Total	4,023	34.4	11.9

[1] Minnesota communities represent 68 percent of this group (1,043 of 1,541). A Minnesota statute requires pricing by weight or volume as a condition for receiving a license for solid waste collection. This statute went into effect in January 1994.

Source: Marie L. Miranda and David Bynum, Unit Based Pricing in the United States: A Tally of Communities, Duke University, 1999.

generated (waste to landfills and incinerators plus recycling plus yard waste collection) does not appear to be significantly different under unit-based pricing from that under a flat-fee system. In other words, unit-based pricing may promote diversion from landfills to recycling and yard waste collection, but it does not appear to promote source reduction behavior.

Since the cost of reducing residential waste may not vary significantly across households, this experience with unit-based pricing may illustrate the merits of a charge approach. The small gains available through a trading approach may be swamped by the costs of acquiring information about potential buyers and sellers and other transactions costs in such a market. Thus very few trades would occur, resulting in little cost savings. In this case where control costs are fairly homogeneous, the charge approach appears to be more appropriate, and in the case of unit-based pricing of solid waste, it has been fairly successful at reducing waste to landfills and incinerators.

Implications of the U.S. Experience

These trading and emissions charge programs illustrate the potential for regulatory strategies to achieve environmental goals through approaches that provide incentives to effectively harness private markets. Of these examples, some have demonstrated more substantial cost savings than others, but in none did the market-oriented approach undermine the achievement of the environmental goal. More cost-effective attainment of environmental goals depended in large part on the design of markets tailored to the specific characteristics of the environmental problem at hand. In cases where emissions sources have roughly equivalent environmental effects, where emissions monitoring is available, and where the cost of reducing emissions varies across sources, trading can be a powerful tool to address pollution cost-effectively. The rules for the design of trading can ensure that the program achieves more of its potential cost-effectiveness. Such rules can include reasonable liability rules, banking and borrowing, and appropriate restrictions on trading, for example to address hot spots. In cases where the costs of reducing pollution are similar across sources, the charge approach may be more appropriate, and as we have seen, it has been used in many U.S. communities to address residential waste generation.

Such incentive-based approaches have also been used in other countries and in other policy contexts. For example, several European countries employ charges on air and water pollution. However, many of these programs are designed more to raise revenue and have minimal effects on emissions because the charges are set too low to induce much emissions abatement. In Singapore a traffic congestion pricing system has been in use since 1975 to reduce the number of vehicles in the central business district. In the United States, tradable permits have also been used to address such problems as overfishing (Box 7-5).

Box 7-5. Individual Quotas for Fisheries Management

Most commercial fisheries are experiencing declining fish stocks because of too much fishing. To prevent overfishing, some fisheries have resorted to fixing the total amount of fish that may be caught in a given year. Fishery managers set this limit, called the total allowable catch (TAC), low enough to guarantee the sustainability of the fishery, and they officially end the season once this limit has been reached. Because fishers know that managers have limited the total catch, their goal becomes to catch as large a fraction of it as possible. The "derbies" that result as each fishing crew tries to beat the rest of the fleet can waste significant resources. Fishers respond by overinvesting in gear and purchasing ever faster, ever larger boats, but these investments only make the derbies more frenetic. The rapid pace has in some cases significantly shortened the fishing season, needlessly restricting consumers' access to some fish species during certain periods and forcing fishers to concentrate their work effort into a shorter period.

Managers have tried to supplement the TAC with gear and access restrictions, but a potentially more efficient approach for some fisheries is to allocate shares of the TAC in the form of individual quotas. Since each fisher then has a right to a specified share of the TAC in a given year, each can catch this share in the cheapest manner possible without having to worry about the behavior of competitors. The incentives to concentrate production in the early portion of the season and to overinvest in capital disappear. And because the quotas can be traded, the market provides an incentive for the most efficient operators to catch the most fish. Less efficient fishers can sell their rights to more efficient fishers for an amount greater than their expected profit on the catch. Similarly, the more efficient fishers stand to net more than the profit of the less efficient ones, and so the individual quotas can be exchanged in such a way that both are better off.

Individual quotas have been used extensively around the world, with very promising results. New Zealand first introduced such a program in 1986, and at least seven other countries now employ individual quotas. Currently three programs operate in the United States, covering fishing for surf clams, ocean quahogs, wreckfish, Alaskan halibut, and Alaskan sablefish. The Sustainable Fisheries Act of 1996 placed a moratorium on the use of individual quotas through October 1, 2000, and requested a study of the quota approach by the National Research Council. The NRC panel released its report in April 1999. It recommended that the Congress lift the 1996 moratorium and allow regional fisheries to use individual quotas. The report emphasized that the quotas are not a panacea applicable to all fisheries. But it also concluded that past

continued on next page...

Box 7-5.—*continued*

experience has repeatedly demonstrated the effectiveness of individual quotas for "matching harvesting and processing capacities to the resource, slowing the race to fish, providing consumers with a better product, and reducing wasteful and dangerous fishing."

Applying the Lessons Learned: Global Climate Change

Perhaps the leading environmental challenge of the 21st century will be to address the risks associated with global climate change. Climate change results from the long-term accumulation of greenhouse gases in the atmosphere. The balance of scientific evidence suggests that emissions of greenhouse gases from human activity have a discernible influence on the global climate. Three characteristics of the climate change challenge create great potential for emissions trading and similar flexibility mechanisms to reduce greenhouse gas emissions. One is that a very large number of sources emit greenhouse gas emissions, which stay in the atmosphere for many years, so that the climatic effect of a unit of emissions is the same no matter where the emissions come from. A second is that the different types of sources have significantly different abatement costs, especially across countries. The number of potential participants and this heterogeneity in their abatement costs provide the basis for an active, competitive emissions trading market. Finally, emissions of carbon dioxide, the most prevalent greenhouse gas resulting from human activity, are relatively easy to calculate.

Emissions of greenhouse gases occur as a by-product of a variety of activities: fossil fuel combustion, deforestation, rice cultivation, maintenance of electricity transformers, aluminum manufacturing, and others. The atmospheric concentration of carbon dioxide has increased about 30 percent since the preindustrial period. Absent new mitigation efforts, that concentration will likely rise to double the preindustrial concentration by the middle part of the 21st century. Moreover, greenhouse gases can reside in the atmosphere for very long periods. Carbon dioxide and nitrous oxide may last in the atmosphere for approximately 100 years, and other greenhouse gases, such as perfluoromethane and perfluoroethane, can last in the atmosphere tens of thousands of years. Such an accumulation of greenhouse gases could pose significant risks, including rising sea levels, more frequent and severe storms, shifts in agricultural growing conditions, increased range and incidence of certain diseases, changes in the availability of freshwater supplies, and damage to ecosystems and biodiversity.

A landmark international agreement to address the risks of climate change was the Framework Convention on Climate Change, signed at the 1992 Earth Summit in Rio de Janeiro. Building on this treaty, 160 countries agreed to the Kyoto Protocol in December 1997. The Kyoto Protocol established binding greenhouse gas emissions targets for 38 industrialized countries for the period from 2008 to 2012. The United States agreed to a target of 7 percent below 1990 emissions levels. To promote cost-effective attainment of these targets, the agreement also established four flexibility mechanisms: emissions target bubbles, international emissions trading, Joint Implementation (JI), and the Clean Development Mechanism (CDM). The last three of these, if designed and implemented efficiently, could provide the foundation for a global emissions market. Since greenhouse gas emissions have the same climatic consequences wherever they occur, the most efficient way to address the risks of climate change is to reduce emissions wherever such reductions are cheapest.

Flexibility Mechanisms in the Kyoto Protocol

Emissions target bubbles effectively allow a group of countries to aggregate their emissions targets into one megatarget and to reallocate emissions to new targets within this group. For example, all the countries of the European Union have Kyoto Protocol targets set at 8 percent below their actual 1990 emissions (written herein as 1990 –8). Under the bubble, the EU target becomes 1990 –8, and individual countries within the group have targets that vary between 1990 –28 and 1990 +27. Thus, those EU countries that expect to find it easier than others to reduce emissions effectively take on bubble allocations below their Kyoto Protocol targets, whereas those that may find the targets more difficult to achieve get bubble allocations in excess of these targets. The bubble concept allows for countries to engage cooperatively in one set of "political trades" before the commitment period. However, once all EU countries have ratified the Kyoto Protocol, the allocations established under the bubble become their new targets.

International emissions trading may occur among all countries with binding emissions targets. With these targets, each country is allowed to emit a specified level of emissions: its so-called emissions allowances. Trading occurs when one country agrees to sell some of its emissions allowances to another country. It can also occur among firms and other private sector entities that hold emissions allowances through domestic trading programs. For example, a U.S. firm that must hold allowances for the U.S. domestic trading program could trade with a Canadian firm that must hold allowances for a Canadian domestic trading program. For countries that have opted for a traditional regulatory approach or a charge approach to controlling emissions, it may still be possible for international trading to occur between firms and governments.

Like international emissions trading, Joint Implementation may occur among countries with binding targets. Unlike international trading, however, JI is focused on projects. A firm in one industrial country may invest in a project to reduce greenhouse gas emissions in another. If both countries' governments approve the project, emissions allowances from the country where the reductions occurred are transferred to the other country in exchange for the investment.

The Clean Development Mechanism allows industrial and developing countries to work together to design and implement projects in developing countries that abate greenhouse gas emissions; however, developing countries do not need binding emissions targets to participate in the CDM. CDM projects must be certified on the basis of several criteria. In addition, a portion of the emissions credits generated by the project would support an adaptation fund for low-income countries especially vulnerable to climate change (adaptation charges) and for administrative costs of the CDM. Industrial countries can use CDM reductions to meet their emissions targets. The rules for international emissions trading, JI, and CDM are expected to be finalized at the next round of climate change negotiations at The Hague later in 2000.

Finally, the protocol allows for emissions allowances to be banked from one commitment period to the next. A 5-year average commitment period provides additional flexibility by effectively allowing for the banking and borrowing of emissions allowances within this period. This opportunity to bank and borrow can smooth out permit prices, which might otherwise experience large price swings due to normal annual fluctuations in the weather or the economy.

Cost-Effectiveness of Kyoto Protocol Flexibility Mechanisms

Although international emissions trading, Joint Implementation, and the Clean Development Mechanism can all help lower the cost of compliance with the Kyoto Protocol targets, their cost-effectiveness may vary. An efficient international emissions trading system would not require case-by-case reviews of trades; however, JI and CDM might require such review, and CDM projects would also require independent certification. Further, the adaptation charges and administrative costs would increase the costs of participating in a CDM project. The reviews and charges associated with project-based approaches could be similar to those in the early emissions trading programs under the Clean Air Act—netting, bubbling, and offsets—which experienced less activity than would have been expected with less bureaucratic oversight. In addition, the project orientation of JI and CDM would effectively exclude some cost-saving efforts. For example, a country pursuing a policy of cutting energy subsidies might find it impossible to classify this policy as a project under JI or CDM.

However, the country could cut energy subsidies and sell unneeded emissions allowances through the international emissions trading mechanism.

An international emissions market based on trading, JI, and CDM could allow substantial gains from trade in meeting emissions targets because the cost of controlling greenhouse gases differs widely from country to country. Countries that have relatively inexpensive ways of controlling greenhouse gases have incentives to reduce emissions by more than their targets require, because they can then sell tradable allowances that they will not need. By the same token, countries facing more expensive emissions abatement measures have incentives to buy less costly allowances from others. Modeling analyses of the Kyoto Protocol have found that, for the United States, moving from a no-international-trading scenario to a scenario of efficient trading among industrial countries would cut the price of a tradable carbon dioxide permit (a measure of marginal compliance cost) by half.

Expanding the Scope of Trading to More Countries

Modeling analyses also illustrate the significant potential for additional cost savings by expanding emissions trading to developing countries. Among the world's large economies, the cost to a country to abate a given percentage of its greenhouse gases may vary by more than a factor of 20. If developing countries adopt binding emissions targets, they can participate in international emissions trading and may gain substantial revenue from selling permits in the international emissions market (Box 7-6). In an efficient global market, low-cost opportunities to reduce greenhouse gases in developing countries would attract foreign direct investment in energy and industrial abatement technologies and for carbon dioxide sequestration activities (such as planting and managing stands of trees to absorb carbon dioxide). Developing countries could generate billions of dollars in revenue annually through the sale of emissions allowances to countries with higher abatement costs. Effectively, the Kyoto Protocol provides the potential for low-cost abating developing countries to create an export industry whose product is emissions abatement. While providing economic and environmental benefits to developing countries, an efficient global trading system could reduce the tradable permit price by up to about 90 percent in the United States.

Expanding the Scope of Trading to More Greenhouse Gases

Expanding the scope of trading could capture even more benefits. Recent analyses have found that allowing for trading across greenhouse gases can lower the cost of meeting emissions targets. Greenhouse gases could be traded on the basis of global warming potentials, which provide a measure of the effect of each

Box 7-6. Expanding the Scope of the Market Through Developing Country Participation

The Kyoto Protocol stipulates that countries must have a binding emissions target before they may engage in international emissions trading. Since the Kyoto conference, developing countries have expressed interest in emissions targets. Consistent with the Framework Convention on Climate Change, targets for developing countries should help promote their sustainable development. For them to do so, such targets should accommodate emissions growth, because some growth in emissions is an unavoidable consequence of development. Unlike the current targets in the Kyoto Protocol, which were set below most countries' current emissions levels, such a target for developing countries could be set above current levels. At the same time, to contribute to the international effort to address climate change risks, such targets should result in real abatement of emissions below levels that would otherwise be reached during the commitment period—that is, below the projected business-as-usual emissions level. This kind of target, often referred to as an emissions growth target, could provide for continued economic development but with a lower emissions growth rate.

Such a target could be expressed as some percentage of a base year, in a fashion similar to current Kyoto Protocol targets, but perhaps with a different base year and/or a percentage greater than 100 percent to account for expected emissions growth. An emissions target could also take other forms. It could, for example, be indexed to a country's economic performance (such as GDP) between now and the 2008-12 commitment period. Such targets could avoid the risk of a crunch arising from faster than projected economic growth between now and the commitment period. Developing countries would face only the much smaller risk that emissions would be higher than expected, given the economic conditions during the commitment period. Similarly, such targets would also avoid the risk of inadvertent laxness associated with lower than expected economic growth between now and the commitment period. This indexed target formulation is reflected in the emissions commitment announced by Argentina at the climate change negotiations held in Bonn, Germany, in the fall of 1999.

gas on the climate. For example, a pound of methane contributes 21 times as much as 1 pound of carbon dioxide to global warming. Thus, reductions in one kind of gas can substitute for increases in another. Absorption of carbon dioxide by planting trees and creating other carbon dioxide "sinks" could also serve as a low-cost substitute for reducing carbon dioxide emissions. Some modeling analyses indicate that efficient intergas trading could reduce costs to the United States by 25 to 40 percent relative to a policy that only reduces carbon dioxide to achieve the target.

Quantitative Restrictions on Trading

Some countries have argued that trading should be quantitatively restricted to ensure substantial domestic emissions abatement. This is somewhat analogous to early Clean Air Act trading rules that required firms to undertake significant emissions abatement before they could buy emissions permits from other firms with lower abatement costs. If this earlier experience is any guide, these types of restrictions on trading would likely raise the cost of compliance significantly, result in a less liquid tradable permit market, and deliver no benefits to the climate over those from a trading system with no quantitative restrictions. Interestingly, the proposal by the European Union to establish quantitative limits on international emissions trading, JI, and CDM would exempt the bubble mechanism, which the European Union has indicated it will use (Box 7-7).

Liability Rules for Trading

Some countries propose that buyers of emissions permits should be liable if the seller does not comply with its emissions target. But such a buyer's liability scheme could present significant uncertainty in the market, increase transactions costs, and risk the further development of the market. The uncertainty about allowance value (that is, whether allowances can be used for a country's compliance) is greatest in a new market where there is no track record for sellers and where market institutions to handle risk have not yet evolved. This uncertainty may preclude trades and prevent a robust allowance market from being established. Bearing risk, or acquiring information to reduce risk, imposes costs on buyers. The imposition of additional costs for undertaking a trade will make some trades unprofitable, thereby increasing compliance costs unnecessarily.

Making Trading Across Countries Work

Finally, the efficiency of an international trading system may be influenced by heterogeneity in domestic abatement programs as well as by lack of experience with trading. For example, some industrial countries may undertake traditional regulatory policies such as mandating fuel economy standards and requiring greenhouse gas performance standards for stationary sources. Such an approach would not provide explicit information about the cost of reducing emissions as would a domestic emissions trading program or a charge program. These countries may find it difficult to assess the nature and extent of their proper economic role in an international emissions market. Without the explicit cost information revealed in a domestic trading program, these countries may buy or sell emissions allowances to a degree that is inconsistent with what is economically optimal. With an efficient

Box 7-7. The EU Bubble Allocation and Restrictions on Kyoto Protocol Mechanisms

In May 1999 the European Union proposed quantitative restrictions on international emissions trading, Joint Implementation, and the Clean Development Mechanism that would limit industrial countries' opportunities to buy and sell emissions. The buying restrictions would take the form of two formulas; countries could choose the less binding of the two. If a country could demonstrate to a review team that domestic abatement measures produced emissions reductions in excess of the binding level, the buying cap could be raised such that purchased allowances equaled verified domestic abatement. The selling restriction also would take the form of a formula, with the opportunity to raise the binding selling cap equal to the amount of verified domestic emissions abatement. The proposed restrictions do not apply to the "political trading" under the bubble provision of the Protocol.

In 1998 the European Union announced its bubble allocation under the Kyoto Protocol. EU members will transfer portions of the group's assigned emissions targets to other EU countries. In the Kyoto Protocol, all EU countries are assigned targets of 1990 –8; under the bubble allocation these adjusted targets would range from 1990 –28 to 1990 +27. The United Kingdom's emissions have fallen since 1990 as a result of liberalizing its electricity sector; Germany's emissions have fallen in the same period in part because of restructuring related to unification with eastern Germany. Therefore these two countries accepted bubble allocations of 1990 –12.5 and 1990 –21, respectively. Since Ireland, Portugal, and Greece are expected to grow faster than most other EU countries, they received bubble allocations ranging from 1990 +13 to 1990 +27.

EU data indicate that several of the political transfers under the bubble allocation would probably not comply with the restrictions proposed by the European Union itself for the other Kyoto Protocol mechanisms. Indeed, 10 of the 15 EU countries could violate the EU proposal to restrict flexibility: 6 could receive transfers in excess of their binding buying constraints, and 4 could transfer emissions in excess of their selling constraints. Thus, two-thirds of EU members might benefit from political trades under the bubble that could not occur as economic trades under its own proposal to restrict international emissions trading, JI, and CDM.

domestic trading program, participating firms would have explicit price-of-abatement information on domestic abatement opportunities to guide their buying and selling in an international emissions market. Even if some countries implement domestic trading programs for one or a few industries, they may still forgo significant cost savings associated with a more comprehensive domestic trading system. Integrating an international emissions market with private firms and national governments may result in some efficiency losses. The U.S. experience in other emissions markets suggests that countries and firms with very little experience at trading may not be as active participants as others.

To promote an efficient international trading system, the Administration has proposed a set of rules for trading based on its experiences with various trading programs. The Administration opposes quantitative restrictions on trading. The Administration supports a system of seller liability for trading, coordinated with a strong compliance system. To promote cost-effectiveness in the trading system, the Administration supports involving interested private entities in international emissions trading, JI, and the CDM. In addition, the Administration has proposed a domestic trading system for greenhouse gases for the 2008-12 commitment period and aims to have this domestic system integrated with international emissions trading. For the near term, the Administration has included a hybrid trading and charge system in its electricity restructuring bill to promote renewable power as a way to encourage the development of emerging renewable energy technologies (Box 7-8). In addition, the Administration has promoted the development and diffusion of more climate-friendly technologies through a variety of R&D and information programs (Box 7-9).

Box 7-8. The Renewable Portfolio Standard

The generation of electricity can result in an array of environmental problems, from emissions of air pollutants, to nuclear waste, to damage to aquatic ecosystems. Renewable sources of energy, such as wind, biomass, solar, and geothermal power, have the potential to deliver electricity while having a more modest impact on the environment. The Administration's bill to restructure the electricity industry—the Comprehensive Electricity Competition Act—calls for a renewable portfolio standard (RPS) to promote the development and use of renewable electricity.

The RPS would require all retail electricity sellers to cover a certain percentage of the electricity they generate with nonhydropower renewable sources of electricity; this percentage would rise from its 1997 level of 2.3 percent to 7.5 percent by 2010. A seller could meet this percentage requirement by generating electricity from its own renewable energy sources or by purchasing tradable renewable electricity credits from others who generate electricity from such sources. In addition, the RPS would be governed by a cost cap of 1.5 cents per kilowatt-hour. If the cost of generating renewable electricity reached 1.5 cents per kilo-

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Box 7-8.—*continued*

watt-hour above the price of nonrenewable electricity, an electricity seller could go to the Department of Energy and purchase an RPS credit for 1.5 cents per kilowatt-hour instead of incurring the greater costs of generating more expensive renewable energy. Revenue from these sales would contribute to a Public Benefits Fund, which is envisioned to support renewable power R&D, energy efficiency programs, and low-income assistance.

The combination of a tradable permit system with the cost cap would allow for considerable flexibility for electricity vendors in meeting the renewable standard. The costs of generating nonhydropower renewable electricity, especially in quantities more than three times that of today, are uncertain. The cost cap would provide additional certainty and a form of insurance to electricity sellers as they plan for investment in new generating technologies. It would also insure their customers against unexpectedly large electricity price changes.

Box 7-9. Climate Research and Development and Information Programs

Potential new technologies often do not receive sufficient private sector investment when investing firms cannot fully capture the benefits of these technologies. For example, some of the benefits of improved solar power technology accrue to society at large, in the form of improved local air quality and reduced carbon dioxide emissions relative to a fossil fuel power alternative. In such cases, producers have less economic incentive to invest in carbon-free power technologies than is socially optimal. Federal support for research and development in cleaner and more energy-efficient technologies can address this problem. Through the President's Climate Change Technology Initiative (CCTI), the Administration has invested $2.12 billion over the past 2 years in clean, energy-efficient technology development and has proposed to spend $1.43 billion in fiscal 2001. The CCTI has funded R&D in technologies associated with the four major sources of carbon dioxide emissions—buildings, industry, transportation, and electric power—and investments in carbon removal and sequestration.

Complementing these R&D programs, efforts to provide more information about the energy and environmental effects of products can promote the deployment of more climate-friendly technologies. Evidence suggests, for example, that better information about the potential cost savings from improving energy efficiency may increase

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Box 7-9.—*continued*

the use of energy-efficient technologies. Lacking this information, consumers may simply purchase the product with the lowest upfront cost, all else equal. However, information about the costs of operating a product over its lifetime may illustrate to the consumer that the life-cycle costs of the more energy-efficient product could be lower than those of the product with the cheaper price tag.

The Energy Star Program at the Environmental Protection Agency provides consumers with information about the energy efficiency of a wide variety of products through a readily identifiable label. Products bearing the Energy Star label appeal to consumers interested in both long-term energy costs and the environmental effects of using energy. Thus, Energy Star office equipment like computers, which are, on average, 50 percent more energy efficient, would be especially attractive to these consumers. In addition, the Administration's electricity restructuring bill includes a labeling provision that requires electricity generators to provide consumers with information about the environmental characteristics of the electricity provided, such as the fuel source. Under this bill, consumers who want to purchase "green" electricity will have the information they need to make such a decision.

Conclusion

Economic activity has long contributed to environmental pollution in one form or another, but the application of incentive-based approaches to repair the damage of pollution has only really come into vogue in the United States over the past 25 years. Experience with tradable emissions permits and emissions charges illustrates the potential for substantial cost savings in achieving environmental goals, as well as some of the pitfalls in designing these policy tools. Taking the characteristics of environmental problems properly into account makes it easier to identify and apply an appropriate regime. Drawing on the U.S. experience with market-oriented regulatory policies, the Administration has advocated and secured the inclusion of international emissions trading, Joint Implementation, and the Clean Development Mechanism in the Kyoto Protocol as ways to achieve the world's climate goals as cost-effectively as possible. Future efforts in negotiations to design rules for greenhouse gas emissions permit trading and to expand the scope of trading will seek to ensure even greater cost-effectiveness.

Among the challenges that lie ahead include an improved application of these tools internationally. Besides the United States, many other industrial countries have employed incentive-based approaches, especially emissions charges, to address environmental pollution. Other countries, especially developing countries with substantial air and water pollution problems, can learn from the experience of the United States and other industrial countries and employ these instruments to achieve better environmental quality with the scarce resources they have available. Further, as countries begin to recognize and address cross-border environmental problems such as greenhouse gas emissions, the potential for cooperative use of incentive-based instruments could provide countries significant cost savings and environmental benefits.