21 Environmental Regulation

The range of activities in the area of environmental regulation is perhaps the most diverse of any regulatory agency.[1] The U.S. Environmental Protection Agency (EPA) has programs to regulate emissions of air pollution from stationary sources, such as power plants, as well as from mobile sources, such as motor vehicles. In addition, it has regulations pertaining to the discharge of water pollutants and other waste products into the environment. These pollutants include not only conventional pollutants, such as the waste by-product of pulp and paper mills, but also toxic pollutants.

In situations in which its regulations of discharges and emissions are not sufficient, the EPA also undertakes efforts to restore the environment to its original condition through waste treatment plants and the removal and disposal of hazardous wastes. Insecticides and chemicals are also within the general jurisdiction of the agency's efforts. Moreover, the time dimension of the agency's concerns is quite sweeping, because the environmental problems being addressed range from imminent health hazards to long-term effects on the climate of Earth that may not be apparent for decades.

In this chapter we will not attempt to provide a comprehensive catalog of environmental regulations, although we will draw on a number of examples in this area. The focus instead will be on the general economic frameworks that are available for analyzing environmental problems. The structure of these problems generally tends to be characterized by similar economic mechanisms for different classes of pollutants. In each case there is a generation of externalities affecting parties who have not contracted to bear the environmental damage. A similar economic framework is consequently applicable to a broad variety of environmental problems.

We will begin with an analysis of the basic economic theory dealing with externalities and then turn to variations in this theory to analyze the choices among policy alternatives. The issues we will address include current policy concerns. Should the EPA pursue various kinds of marketable permit schemes or rely on technology-based standards?[2] In addition, there is increasing concern with long-term environmental risks associated with climate change. How should we conceptualize the economic approach to regulating these and other risks that pose new classes of environmental problems? Finally, we will review the character of the enforcement of environmental regulation, as well as the ultimate impact of environmental policy on environmental quality.

1. For an excellent overview of environmental policy, see the Council on Environmental Quality, *Environmental Quality*, 21st Annual Report (Washington, D.C.: U.S. Government Printing Office, 1991). Chapters 1 and 2 provide overviews of environmental policy and the benefits and costs of these efforts.

2. For a detailed description of these policy options, see Robert W. Hahn and Gordon L. Hester, "Where Did All the Markets Go? An Analysis of EPA's Emissions Trading Program," *Yale Journal on Regulation* 6, no. 1 (1989): 109–54.

The Coase Theorem for Externalities

The fundamental theorem in the area of externalities was developed by Ronald Coase.[3] The generic problem that he considered was that of a cattle rancher. Suppose that farm A raises cattle, but that these cattle stray onto the fields in farm B, damaging farm B's crops. The straying cattle consequently inflict an externality on farm B.

What Coase indicated is that assessing these issues is often quite complex. Among the issues that must be considered from an economic standpoint are the following. Should the cattle be allowed to stray from farm A to farm B? Should farm A be required to put up a fence, and if so, who should pay for it? What are the implications from an economic standpoint if farm A is assigned the property rights and farm B can compensate farm A for putting up a fence? Alternatively, if we were to assign the property rights to the victim in this situation, farm B, what would be the economic implications of assigning the property rights to farm A?[4]

The perhaps surprising result developed by Coase is that from an economic efficiency standpoint, the fencing outcome will be the same irrespective of the assignment of property rights. If we assign the right to let cattle stray to farm A, then farm B will bribe farm A to construct a fence if the damage caused to farm B's crops exceeds the cost of the fence. Thus, whenever it is efficient to construct a fence, farm B will compensate farm A and contract voluntarily to purchase the externality so as to eliminate it.

Alternatively, if we were to assign the property rights to farm B, farm A could construct the fence to prevent the damage. If the cost of such a fence exceeded the damage being inflicted, farm A could contract with farm B to compensate farm B for the damage imposed by the straying cattle. In each case, we will obtain the same result in terms of whether or not the fence is constructed irrespective of whether we give farm A or farm B the property rights.

From an equity standpoint, the results are, however, quite different. If we assign the property rights to farm A, then farm B must compensate farm A to construct the fence, or alternatively farm B must suffer the damage. In contrast, if we were to assign the property rights to farm B, the cost of the fence construction or the cost of compensation for the damage would be imposed on farm A. The outcome in terms of whether the crops will be trampled or the fence will be constructed will be the same regardless of the property right assignment. However, the well-being of each of the parties and the cash transfers that take place will be quite different under the two regimes.

3. See Ronald H. Coase, "The Problem of Social Cost," *Journal of Law and Economics* (1960): 1–44. The Coase theorem has given rise to a large body of work in the field of law and economics. See, in particular, Richard A. Posner, *Economic Analysis of Law*, 6th ed. (Boston: Little, Brown, 2003).

4. One observant student noted that the manure left by the stray cows on farm B may be a positive externality. For concreteness, we will assume the net externality is negative.

Economists generally have little of a conclusive nature to say about which situation is more equitable. Coase observed that we should not be too hasty in making a judgment of which property right assignment was most fair. From an equity standpoint one should take into account the reciprocal nature of the problem. In this situation, farm A inflicts harm on farm B. However, to avoid the harm to farm B we must harm farm A. The objective from an efficiency standpoint is to avoid the more serious harm.

The Coase Theorem as a Bargaining Game

What Coase did not explore in detail was the nature of the bargaining process that would lead to the efficient outcome that he discussed. To address these issues, it is useful to cast the Coase theorem problem within the context of a simple bargaining game. For concreteness, let us suppose that the property rights are being assigned to the pollution victims, so that it is the firm that must pay for the damage or control costs.

Table 21.1 summarizes the generic components of this and other bargaining games. The company in this situation has a maximum offer amount that it is willing to give the pollution victims for the damage being inflicted. The factors driving the maximum offer value are the expenditures that the firm would have to make to eliminate the externality of the cost that would be imposed on the firm by the legal rules addressing involuntary externalities. The maximum amount that the firm will be willing to pay will be the minimum of either the control costs or the penalty that will be imposed on the firm if it inflicts the externality.

From the standpoint of the individuals bearing the accident costs, the minimum amount they are willing to accept in return for suffering the impacts of the pollution will be that amount of compensation that restores their level of utility to what it would have been in the absence of pollution. We will refer to this amount as the minimum acceptance value.

There is a potentially feasible bargaining range if the maximum offer the firms are willing to make exceeds the minimum acceptance amount, which is the first inequality

Table 21.1
The Coase Theorem Bargaining Game

Feasible bargaining requirement:

$$\text{Maximum offer} \geq \text{Minimum acceptance}$$

Bargaining rent:

$$\text{Bargaining rent} = \text{Maximum offer} - \text{Minimum acceptance}$$

Settlement with equal bargaining power:

$$\text{Settlement outcome} = \frac{\text{Maximum offer} + \text{Minimum acceptance}}{2}$$
$$= \text{Minimum acceptance} + 0.5\text{Bargaining rent}$$

listed at the top of table 21.1. If this condition is not satisfied, no bargain will take place, inasmuch as there is no feasible bargaining range. In such a situation, in which the minimum acceptance amount by the pollution victims exceeds the maximum amount firms are willing to offer, there will be no contractual solution. Firms will select the minimum-cost alternative of either installing the control device or paying the legally required damages amount. The absence of a feasible bargaining range does not imply that the Coase theorem is not true or that the market has broken down. Rather, it simply indicates that there is no room for constructive bargaining between the two parties. In such situations, the resolution of the bargaining game will be dictated by the initial assignment of property rights.

An essential component of the bargaining game is the bargaining rent. This rent represents the net potential gains that will be shared by the two parties as a result of being able to strike a bargain. As indicated in table 21.1, the bargaining rent is defined as the difference between the maximum offer amount and the minimum acceptance value.

This definition is quite general and pertains to other bargaining situations as well. For example, suppose that you were willing to pay $18,000 for a new Honda Accord, but the cost to the dealer of this car is $15,000. There is a $3,000 spread between your maximum offer and the minimum acceptance amount by the dealer, which represents the bargaining rent available. The objective of each of you is to capture as much of the rent as possible. You would like to push the dealer as close to the minimum acceptance amount as possible, and the dealer would like to push you to your reservation price. Much of the bargaining process is spent trying to ascertain the minimum offer and maximum acceptance amounts, because these values are not generally disclosed. Moreover, in the process of trying to learn these values, one may reveal considerable information regarding one's bargaining skill and knowledge of the other party's reservation price. A bid for the car that is substantially below the cost to the dealer, for example, does not indicate that one is a shrewd and tough bargainer, but rather usually suggests that one does not have a well-developed sense of the appropriate price for the car. In a situation in which the parties are equally matched with equal bargaining power, they will split the economic rent.

This symmetric bargaining weight situation provides a convenient reference point for analyzing the bargaining outcome. As indicated in table 21.1, if there is such symmetry the settlement outcome will simply be an average of the maximum offer and the minimum acceptance amount, which is equivalent to the minimum acceptance amount plus one-half of the economic rent at stake.

A Pollution Example

To illustrate these concepts, let us consider the pollution problem summarized in table 21.2. The upstream pulp and paper mill emits discharges that impose $500 of environmental damage. The citizens can eliminate this damage by constructing a water purification plant for

Table 21.2
Property Right Assignment and the Bargaining Outcome

Basic aspects of the pollution problem			
	Primary treatment of effluent: $100	Water purification < costs: $300	Environmental < damage: $500
Bargaining with victim-assigned property rights			
Bargaining equation:	Maximum offer by company = $100: < Minimum acceptance by citizens = $300:		
Outcome:	Company installs controls. No cash transfer.		
Bargaining with polluter-assigned property rights			
Bargaining equation:	Maximum offer by citizens = $300: > Minimum acceptance by company = $100:		
Outcome:	Citizens pay company $100 to install controls and also pay company $100 share of rent if equal bargaining power.		

a cost of $300. Finally, suppose that the company could eliminate this pollution through primary treatment at the plant for a cost of $100.

To see the impact that differences in the property right assignment make, consider first the situation in which the citizen victims of pollution are assigned the property rights. In this context, it is the company that must bribe the citizens for the right to pollute. The maximum amount the polluting firm is willing to pay for this pollution privilege is $100—the cost of installing a treatment facility. The citizens, however, have a reservation price of $300—the lesser of the costs of the water pollution treatment and the environmental damage. Because the maximum offer amount is below the minimum acceptance value, there is no profitable bargain that can be made by the two parties. The result will be that the company will install the pollution treatment system, and there will be no cash transfer between the parties.

The second situation considered is one in which the polluter has been assigned the property rights. In this situation, the maximum offer by the citizens to the firm will be $300. This amount exceeds the $100 cost of installing water pollution treatment for the company, which is the company's minimum acceptance amount. As a result, there is a profitable bargain that can be arranged between the two parties, with a total bargaining rent of $200. The outcome will be that the citizens will pay the company $100 to install the pollution control device. Moreover, if the bargaining power of the two parties is equal, the citizens will also pay the firm an additional $100 as the company's share of the bargaining rent.

Utilization of this bargaining game framework to analyze the Coasian pollution problems provides a more realistic perspective on what will actually transpire than did the original Coase paper, which assumed that the purchase price for the transfers will equal the minimum acceptance amount by the party holding the property rights. In each case, the pollution control outcome is the same, as the company will install the water treatment device. However, in the case where citizens do not have the property rights, not only will they have to pay for the water treatment, they will also have to make an additional $100 transfer to the company that they would not have had to make had they been given the property rights.

The difference in the equity of the two situations is substantial. The citizens must spend $200 if they do not have the property rights—$100 for the treatment cost and $100 to induce the company to install it. If the citizens have the property rights, the cost is $100 to the company for treatment. In each case, the water treatment is the same.

Long-Run Efficiency Concerns

What should also be emphasized is that this short-run equity issue is also a long-run efficiency issue. Ideally, we want the incentives for entry of new firms into the industry to be governed by the full resource costs associated with their activities. If firms are in effect being subsidized for their pollution by citizens paying for their pollution control equipment, then there will be too much entry and too much economic activity in the polluting industries of the economy. We will return to this point within the context of the debate over standards versus taxes. This long-run efficiency point is often ignored by policymakers and by economists who focus on the short-run pollution outcome rather than on the long-run incentives that the property right assignment may create.

Transaction Costs and Other Problems

One factor pertaining to the bargaining process that Coase noted is that there may be substantial transaction costs involved in carrying out these bargains. Although we can generate an efficient outcome through a contractual solution without the need for any regulation, achieving this outcome may be quite costly. If there is a large number of citizens whose actions must be coordinated, then the cost may be substantial. These coordination costs are likely to be particularly large in situations in which there are free—riders. Some individuals may not wish to contribute to the pollution control effort in hopes of obtaining the benefits of controls without contributing to them.

It has often been remarked that there is also a potential for strategic behavior. Some parties may behave irrationally in the bargaining process. However, by modeling the contractual components of the externality market in table 21.2 using an explicit model of the bargaining structure, we capture these aspects within the context of a rational game theory model. It may, of course, be true that people are irrational, but this is true of any economic context and is not a phenomenon unique to externality bargaining contexts. For example, people may misperceive the probability of a particular bargaining response or may not assess the reservation price of the other party correctly.

Perhaps the greatest caveat pertains to the degree to which we can distinguish discrete and well-defined assignments of the property rights. Even in situations in which there is a property right assignment, there are often limitations on the use of these property rights. Moreover, when the courts must enforce these rights, there is often imperfect information. The courts, for example, do not know the actual damages the citizens may incur. Moreover, they may not know with perfect certainty the pollution control and treatment costs. There are also costs to acquiring this information, and within the context of most judicial settings there is substantial error in the information being provided to the court.

The net result is that in actual practice we do not generally turn the market loose and let people contract out of the externalities that are imposed. The victims in the eastern United States who suffer the consequences of the acid rain generated by power plants in the Midwest cannot easily contract with these electric power plants. Even more difficult would be attempting to contract with the automobile users in the Midwest to alter their behavior. The bargaining costs and free-rider problems would be insurmountable. Indeed, in many cases we cannot even identify the party with whom we might strike a bargain. Unlabeled drums of toxic waste in a landfill do not provide a convenient starting point for externality contracts.

Despite the many limitations of the voluntary contractual approach to externalities, the Coase theorem does serve an important purpose from the standpoint of regulatory economics.[5] In particular, by assessing the outcome that would prevail with an efficient market given different assignments of the property rights, one can better ascertain the character of the impact of a particular regulatory program. To the extent that the purpose of government regulation is to eliminate market failures and to ensure efficiency, the implications of the Coase theorem provide us with frames of reference that can be applied in assessing the character of the different situations that will prevail under alternative regulatory regimes. These concerns will be particularly prominent with respect to market-oriented regulatory alternatives that involve the explicit pricing of pollution.

Smoking Externalities

An interesting application of the Coase theorem is to cigarette smoking. Environmental tobacco smoke has become an increasingly prominent public concern and a classic externality issue. Many nonsmokers find cigarette smoke unpleasant, and government agencies such as the EPA and OSHA have concluded that there may be some adverse health effects as well, though the extent of these effects remains controversial. Indeed, a 1998 U.S. district court decision in the *Flue-Cured Tobacco* case rejected the EPA study as a sound basis for policy because it had "cherry picked" its data rather than doing a more comprehensive and balanced analysis.

Whether the health risks of environmental tobacco smoke are large or small, real or imagined, is not essential for addressing these exposures and is not critical to how the Coase

5. The role of the Coase theorem in regulatory contexts is also elucidated in A. Mitchell Polinsky, *An Introduction to Law and Economics*, 3rd ed. (Boston: Aspen, 2003).

theorem will operate in this instance. What is important from the standpoint of the Coase theorem problem is that nonsmokers would be willing to pay a positive amount of money to avoid being exposed to environmental tobacco smoke. Similarly, smokers would be willing to pay to be able to smoke in public places where they generate environmental tobacco smoke. As in the case of the Coase theorem problem, the externalities are in many respects symmetric. Smoking will make the smoker better off and the nonsmoker worse off, whereas restricting smoking will make the smoker worse off and the nonsmoker better off. This is the classic Coase situation.

Applying the Coase logic, one might expect the nonsmokers in restaurants to walk over to the smokers' tables and attempt to strike a bargain to get them to stop smoking. Doing so, however, is unpleasant and consequently costly. However, there are other economic mechanisms that can reflect these concerns. If the restaurant does not have a suitable policy with respect to smoking, customers can eat elsewhere. In effect, the market operation in this context will be through the price system. The smoking policy of the restaurant is a local public good in much the same way as the music, the lighting, and the overall restaurant environment one. In situations in which customers are free to patronize different restaurants, the major remaining concern presumably would be with those who have found that they have made a mistake after arriving at the restaurant for the first time and finding it difficult to go elsewhere. Workplaces have responded similarly to the concerns of workers, inasmuch as some of them have banned smoking and others have instituted smoking areas.

The government has also become active in this area, as hundreds of local governments have enacted various kinds of smoking restrictions. While some national regulations have been proposed, many state regulations have been enacted.[6] As of 1999, all but eight states had enacted smoking restrictions for hospitals, but only four states had enacted any kind of restrictions on smoking in bars, such as separate smoking areas. Enclosed arenas have tended to be regulatory targets, while malls have not. The overall pattern is consistent with what the Coase theorem would suggest in that the areas where the harm is greatest would emerge as the first candidates for regulation. The difference is that the mechanism is not private Coasean bargains, which would be quite costly to organize, but rather coordinated regulatory action. Interestingly, even a majority of smokers support smoking bans for hospitals and indoor sporting events, so that for some forms of smoking restrictions there are common rather than conflicting interests. The reliance on regulatory solutions even in situations when both smokers and nonsmokers may support restrictions highlights the important role of regulations to implement desirable social policies in situations where there are costly impediments to individual Coasean bargains.

6. The data described below are drawn from Joni Hersch, Alison Del Rossi, and W. Kip Viscusi, "Voter Preferences and State Regulation of Smoking," *Economic Inquiry* 42 (2004).

While private Coasean bargains to solve regulatory problems are not the norm, the Coase framework provides a useful approach to guide our thinking about which regulation contexts the market will be expected to work in and which it will not work in. Moreover, if it is believed that the market will not work, should one then inquire what are the efficiency effects on both parties? What are the losses to the parties from the current situation, and what will be the losses with regulation? This is the essential message of the Coase theorem that is pertinent to all such externality contexts.

A final set of externalities associated with smoking pertain to insurance. If smoking is risky, as is the scientific consensus, then presumably the adverse health consequences will have widespread consequences for insurance costs. Health costs will clearly be higher. However, because smokers will die sooner under this scenario, their early departure will save society pension and Social Security costs. A comprehensive tally of these effects appears in table 21.3. As is indicated by the summary of the insurance externalities in table 21.3, the cost per pack generated by smokers is particularly high for health insurance. However, there are offsetting savings arising from the higher mortality rates of smoking, chiefly the lower pension and Social Security costs. Because smokers die sooner, they are also less likely to get long-term diseases such as Alzheimer's, thus diminishing some of their medical expenses later in life. On balance, smokers save money for society in terms of the net externality cost. This result does not mean that smoking is not consequential for the individuals whose lives are at risk or for the particular insurance programs whose costs are affected, nor does it mean that the death of smokers is a desirable social outcome. However, this result does suggest that many externalities often involve competing effects with fairly complex ramifications.

The medical costs associated with smoking led to a wave of lawsuits by the states that in 1998 produced a $206 billion out-of-court settlement by the cigarette industry with forty-six

Table 21.3
External Insurance Costs per Pack of Cigarettes with Tar Adjustments

	Discount Rate (3 percent)
Costs	
Total medical care	0.580
Sick leave	0.013
Group life insurance	0.114
Nursing home care	–0.239
Retirement and pension	–1.259
Fires	0.017
Taxes on earnings	0.425
Total net costs	–0.319

Source: W. Kip Viscusi, *Smoke-Filled Rooms: A Postmortem on the Tobacco Deal* (Chicago: University of Chicago Press, 2002).

states and separate agreements for $37 billion with four other states. Setting aside the merits of the suits and the particular settlement amount, how would one wish to structure the costs imposed on the cigarette industry in order to provide appropriate economic incentives, assuming that this payment reflects the financial externality generated? Many opponents of the cigarette industry want the cost to be imposed through a lump-sum imposition on the companies, so that the costs will come directly out of corporate profits; however, a profit tax will not affect the marginal cost of production or the product price. Another possibility is to link the payment to the level of cigarette sales, which is the approach that has been taken. The net effect is that consumers will, in effect, pay for most of this cost through higher cigarette prices rather than having the cost paid directly by the corporations. Such incentive effects are exactly what we would want to promote in order to foster efficient economic behavior whereby the parties generating costs will be cognizant of the economic consequences of their actions. Boosting the price of cigarettes in this manner is exactly analogous to proposals that firms should pay pollution taxes to reflect the environmental damage they generate, as such taxes will induce more efficient behavior.

Special Features of Environmental Contexts

In environmental contexts, it should also be noted that the character of the markets that would emerge if we set up a market for pollution may be quite unusual. Most existing water pollution regulation is based on the assumption that the usability of water tends to follow a step function, such as the one indicated in figure 21.1.[7] Initially, the water quality is quite high, and we will label the water pristine. After a certain level of pollution the water is no longer pristine, but you can still drink it. After another increase in pollution the usability of the water for drinking declines, but you can swim in the water with appropriate vaccinations. As the pollution level increases further, water is suitable for fishing but no longer for the other uses. Finally, with a very high level of pollution, even the fishing option disappears. At this high pollution level, there is no additional marginal cost being imposed on the citizenry from additional pollution if we assume for concreteness that all of the beneficial uses of the water have disappeared. The citizens could then sell an infinite number of pollution rights without suffering any additional damage beyond what they have already suffered. Moreover, within any particular step of the declining water-quality curve in figure 21.1 there is no loss to the citizenry, so that the marginal costs to them of selling additional pollution rights will be zero.

7. Figure 21.1 is a bit of a simplification of our current understanding of water-quality levels. Although the EPA formerly used a water-quality ladder similar to that shown in this diagram, it is now believed that such a rigorous step function does not in fact hold. Rather, the EPA considers the following four different dimensions of water quality: drinking, swimming, fishing, and aquatic uses. The scores on these various dimensions are correlated in the same direction as would be the case if a water-quality ladder existed, and it remains the case that water that is not safe for any of these uses will exhibit the kind of nonconvexity that we will discuss.

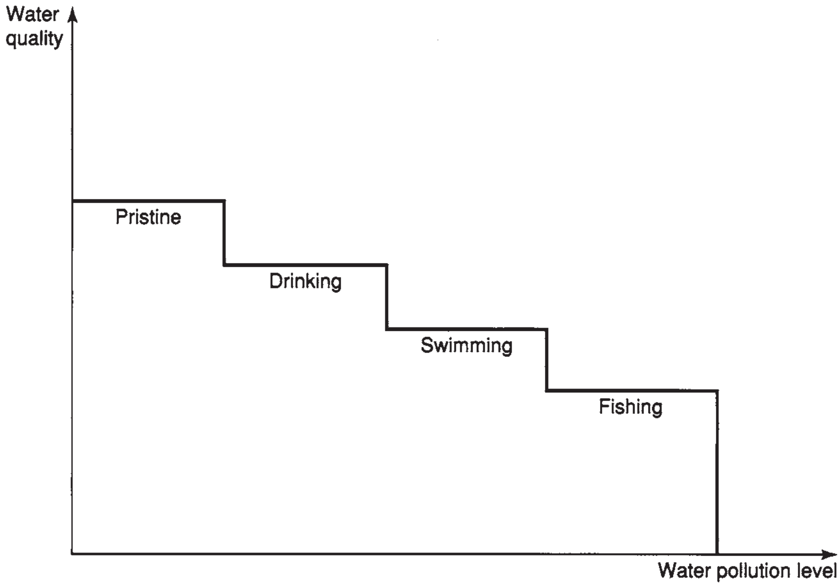

Figure 21.1
Changes in Water Usage as a Function of Pollution

This character of environmental contexts—known formally as an example of *nonconvexities*—suggests that instead of always dispersing the risks, it may be profitable to concentrate the risks in a particular location. For example, are we better off siting hazardous wastes throughout the United States, or should they be concentrated in one area? If they are concentrated, society can adapt by prohibiting residential housing and commercial operations near the facility, so that a large environmental risk can be present without imposing substantial costs on society. In contrast, dispersing hazardous wastes on a uniform basis throughout the United States may appear more equitable, but it will impose larger risks to society at large because it is more difficult to isolate such a large number of individual risks.

The main difficulty with concentrating the risk in this manner involves the appropriate compensation of those who are unlucky enough to have been selected to be put at risk. The option of concentrating the risk is particularly attractive in theory, but in practice it implies that one group in particular will bear a substantial part of the costs. The NIMBY—not in my backyard—phenomenon looms particularly large in such contexts. It is these kinds of equity issues and the potential role for compensation of various kinds that are highlighted by application of the Coase theorem and the implications that can be developed from it.

Siting Nuclear Wastes

These issues concerning the siting of hazardous wastes are abstractions for pedagogical purposes. The nuclear waste repository debate has highlighted the practical importance of these efficiency and equity concerns. The government had invested $9 billion to develop the Yucca Mountain site in Nevada as the central repository for unspent nuclear fuel. The alternative was to scatter the wastes more diffusely across sixty-eight different sites. A central, safe location that embodied a large investment to ensure a low risk level had considerable appeal from an efficiency standpoint. In 2004 a U.S. court of appeals focused on the risk issues and ruled that the facility's protections extending for 10,000 years were too short. Matters become muddied even further as the NIMBY concerns entered the political arena debate during the 2004 presidential campaign.

The problem that prompted this controversy was that some risk could emerge under longer time horizons than the 10,000-year period for which safety would be assured. A National Academy of Sciences panel concluded that in 270,000 years, a person standing just outside the fence could be exposed to sixty times the allowable radiation dose. This allowable dosage threshold is not linked to a specific risk probability, but there is the belief that the risk level is not zero. As a result, the panel recommended that the safety standard be extended for 300,000 years.

How might economists have approached these nuclear waste siting issues differently? A useful starting point would be to assess the technological risk trade-offs involved. The Yucca Mountain site may not be risk-free forever, but scattering nuclear wastes across the country poses more substantial, immediate risks. So when judging any waste siting policy, the comparison should be with the available policy alternatives, not a costless, risk-free world that does not exist.

The scenarios under which the Yucca Mountain site could become risky have a certain element of science fiction about them. After all, 270,000 years away is a pretty long time. A lot could happen on the technological front over that period, making it possible to address the nuclear waste risks more effectively and more cheaply. The cost of remedial measures to address problems that may develop surely will go down over time, so that risk estimates based on current capabilities will be too high.

Discounting also will all but eliminate these far-distant risks as a matter of concern. Suppose we adopt a modest discount rate of 3 percent. Then a dollar of benefits 270,000 years from now has a present discounted value of $(1/1.03)^{270{,}000}$. To see the effect of discounting, consider the following example. Instead of having only one person exposed to radiation at the Yucca Mountain fence, suppose we crammed 300 million people up against the fence. Also assume a worst case of radiation exposure that leads all of them to experience fatal cases of cancer. (Note that the future risk could have been eliminated by not letting people live in close proximity to the site.) On a discounted basis, the result of having 300 million people exposed to risk at the site would be the equivalent of a one in 100,000 chance of cancer today for a single person. Quite simply, any reasonable discounting of effects that are hundreds of thousands of years away will all but eliminate them from the analysis.

But what if we don't worry about discounting, and suppose that for another $9 billion, Yucca Mountain could be made safe for 300,000 years. Wouldn't that be the risk-reducing choice? Such an investment may not be safer from a net health standpoint. As the risk-risk analysis in chapter 20 indicated, there is an opportunity cost of expenditures so that, according to some estimates, there is one statistical death for every $20 million that we divert from the usual bundle of consumer purchases. Spending another $9 billion of taxpayer money will be that much less that is not spent to improve people's standard of living and will lead to 450 expected deaths today. So, if we abstract from financial considerations and focus strictly on health, the question becomes whether the remote discounted value of the small risks 270,000 years from now outweigh the 450 immediate deaths.

The economists' framework for conceptualizing these issues is consequently quite different from that of scientists. The questions posed are not in terms of the period of time over which Yucca Mountain will be completely safe. Rather, what is the magnitude of these risks? What are the costs and benefits of reducing the risks? How do these policy options compare with other available choices? Will changes over time alter the costs of risk reduction? And, what are the opportunity costs in terms of money and lives if we adopt a particular strategy?

Selecting the Optimal Policy: Standards versus Fines

Lawyers and economists generally have different answers to the question of how one should structure regulatory policy. In situations in which there is an externality that we would like to prevent, the answer given by lawyers is to set a standard prescribing the behavior that is acceptable. The usual approach by economists is somewhat different, as they attempt to replicate what would have occurred in an efficient market by establishing a pricing mechanism for pollution.

As we will see, each of these approaches can potentially lead to the efficient degree of pollution control, depending on how the standards and fees are set. In analyzing these pollution control options, we will assume that society approaches the control decision with the objective of providing for an efficient degree of pollution control. In tightening the pollution control standard, we should consequently not do so past the point where the marginal benefits accruing to society from this tightening no longer exceed the marginal costs.

In practice, the standard setting guidelines administered by the EPA are much more stringent. In the case of the Clean Air Act, for example, the EPA is required by law to set ambient air quality standards irrespective of cost considerations. Moreover, not only is the EPA

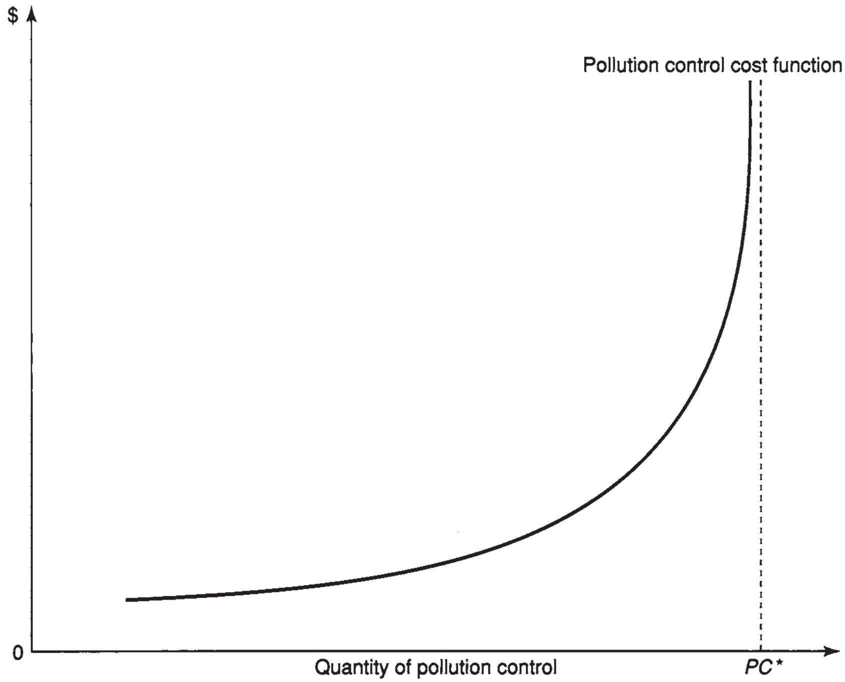

Figure 21.2
Technology-Based Standard Setting

required to ignore costs, ensuring safety is not sufficient. The agency's legislation requires it to provide a "margin of safety" below the zero-risk level. The result is that standards are generally set at excessively stringent levels from the standpoint of equating marginal benefits and marginal costs, but there are informal efforts to achieve balancing based on affordability.

Figure 21.2 illustrates the character of the compliance costs with the degree of pollution control. By making allowances with respect to the availability and affordability of technologies, the EPA and other risk regulation agencies attempt to limit the stringency of their regulations to a point such as *PC**, where the cost function begins to rise quite steeply. Such informal considerations of affordability may limit the most extreme excesses of regulatory cost impacts.

Setting the Pollution Tax

The shortcomings in the market that give rise to the rationale for government regulation stem not only from the character of the cost function but also from the relationship of these costs

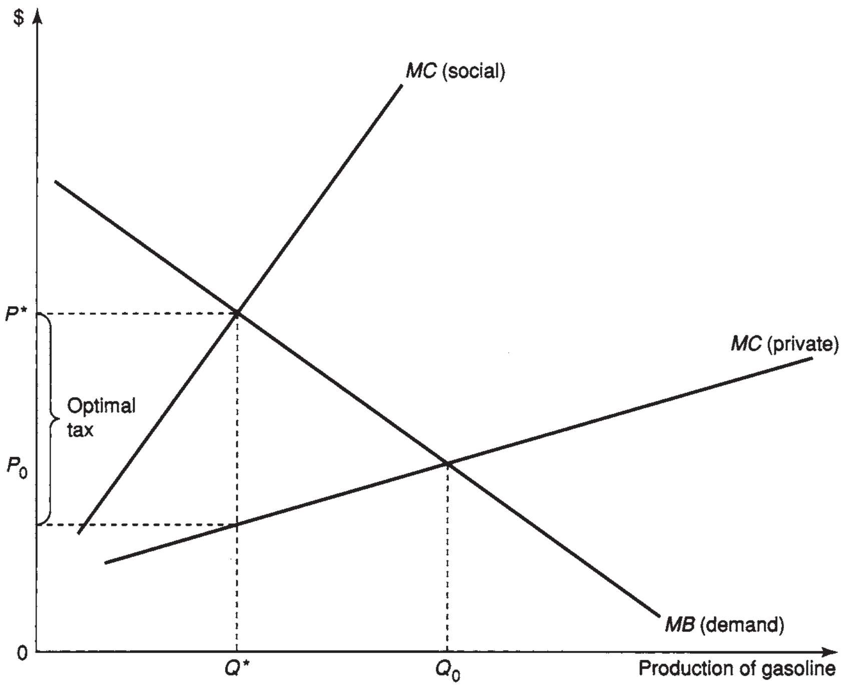

Figure 21.3
Market Equilibrium versus Social Optimum

to the benefits of controlling environmental externalities that would not otherwise be handled in an unregulated market context. Figure 21.3 indicates the nature of the market equilibrium in a situation in which the externality is not priced, but rather was inflicted involuntarily on the citizenry. The focus of this curve is on the marginal benefits and marginal costs of the production of gasoline, where the externality consists of air pollution. The market is governed by the relationship of the demand for gasoline, given by the marginal benefit curve *MB*. In setting the quantity level that will be produced, the market will be guided by the marginal cost curve reflecting the private marginal cost of gasoline, leading to a production of gasoline given by Q_0, whereas the socially optimal level of gasoline production is Q^*. The prevailing market price for gasoline is given by P_0. To achieve efficient pricing of gasoline, what is needed is an optimal tax that raises the price of gasoline to the amount P^*. Alternatively, this purpose can be achieved by constraining the quantity of gasoline produced to Q^*, where market forces will drive the price of gasoline up to the point P^*.

Focusing on either prices or quantities can each achieve the desired result. In the case of the quantity restrictions, the revenues accruing from the higher price of gasoline will go to the companies producing gasoline, whereas under a tax scheme the taxes will go to the government.

The choice between taxes and quantity constraints is not simply a question of administrative feasibility. There are also important dollar stakes involved in terms of the transfers among the various market participants. Because market outcomes will produce too much of the externality, some form of government intervention is potentially warranted. If we adopt the usual approach in which we wish to establish the appropriate pollution control standard, the objective is to equalize the marginal benefits and marginal costs of pollution reduction.

The Role of Heterogeneity

Figure 21.4 illustrates the marginal cost curve for pollution reduction to two firms. Firm 1 has a higher control cost for pollution, as is reflected in its higher marginal cost curve MC_1. Firm 2 has a lower pollution reduction marginal cost curve given by MC_2. In situations in which the cost curves differ and where we can make distinctions among firms, the optimal solution is to have a differential standard in different contexts. Thus we should set a tighter

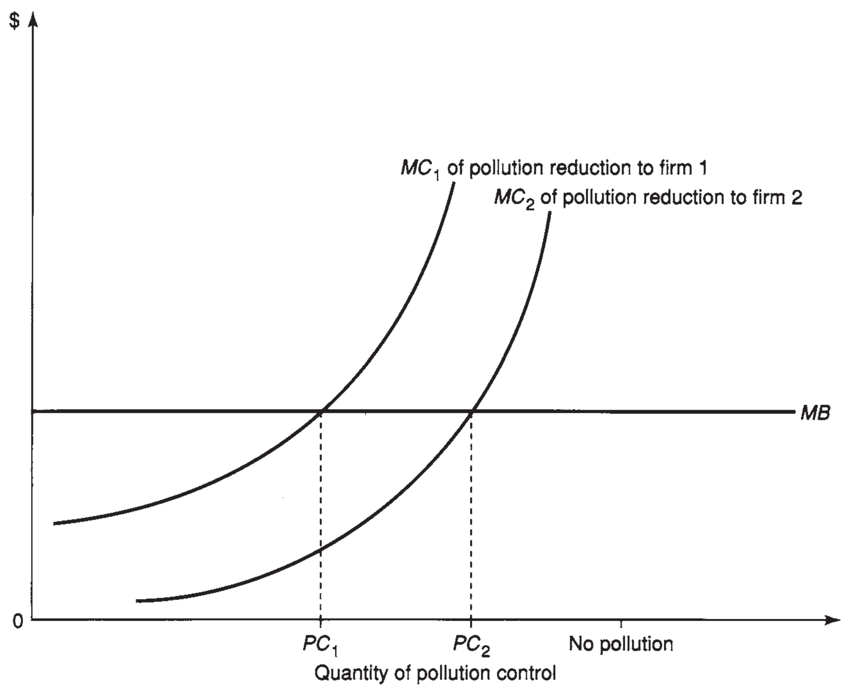

Figure 21.4
Differences in Control Technologies and Efficiency of Pollution Outcome

standard in the situation in which the marginal cost curve is lower, and we can achieve pollution control level PC_2, as compared with the looser standard of PC_1 for the higher-cost firm.

Distinctions such as this arise often among industries. It may be easier for some industries to comply with pollution requirements given the character of their technologies. If it is easier for chemical plants to reduce their water pollutant discharges than it is for dye manufacturers, then we should set the standard more stringently in that case to recognize the difference in the marginal costs of compliance.

Perhaps more controversial are the distinctions that regulatory agencies make among firms within a given industry depending on the character of their technology. For new facilities that can incorporate the new pollution equipment as part of the plant design, the marginal cost curve for compliance is generally less than it will be for an existing facility that must retrofit the pollution control equipment onto its existing technology. It is consequently optimal from an economic standpoint to impose stricter standards on new sources than on existing sources because of the differences in the marginal cost curves.

This economic principle has given rise to what many observers have identified as a “new source bias” in the policies of the EPA and other government agencies.[8] A new source bias is efficient, but one must be careful in determining the extent to which one will have biased policies that set differential standards. For firms such as those in figure 21.4, one can justify the differing degrees of stringency indicated by the difference in marginal costs. The danger is that we often move beyond such distinctions because of political pressures exerted by the representatives from existing and declining industrial regions that are attempting to diminish the competition from the growth areas of the economy, as B. Peter Pashigian has shown.[9] Economics provides a rationale for some new source bias, but it does not necessarily justify the extent of the new source bias that has been incorporated within the context of EPA policy.

The Role of Uncertainty

Setting the optimal standard is most straightforward when compliance costs and benefits arising from policies are known. In the usual policy context, there is substantial uncertainty regarding these magnitudes. Figure 21.5 illustrates the familiar case in which the cost uncertainty is likely to be greater than the benefits uncertainty. For most policies with comparatively small impacts on the nation’s environment, the marginal benefit curve will be flat. Firms’ marginal cost curves for pollution control are not flat but rather tend to slope upward quite steeply. Moreover, there may be considerable uncertainty regarding the degree of

8. For more detailed exploration of new source bias, see Robert W. Crandall, *Controlling Industrial Pollution: The Economics and Politics of Clean Air* (Washington, D.C.: Brookings Institution, 1983).

9. See B. Peter Pashigian, “Environmental Regulation: Whose Self-Interests Are Being Protected?” *Economic Inquiry* 23(4) (1985): 551–84.

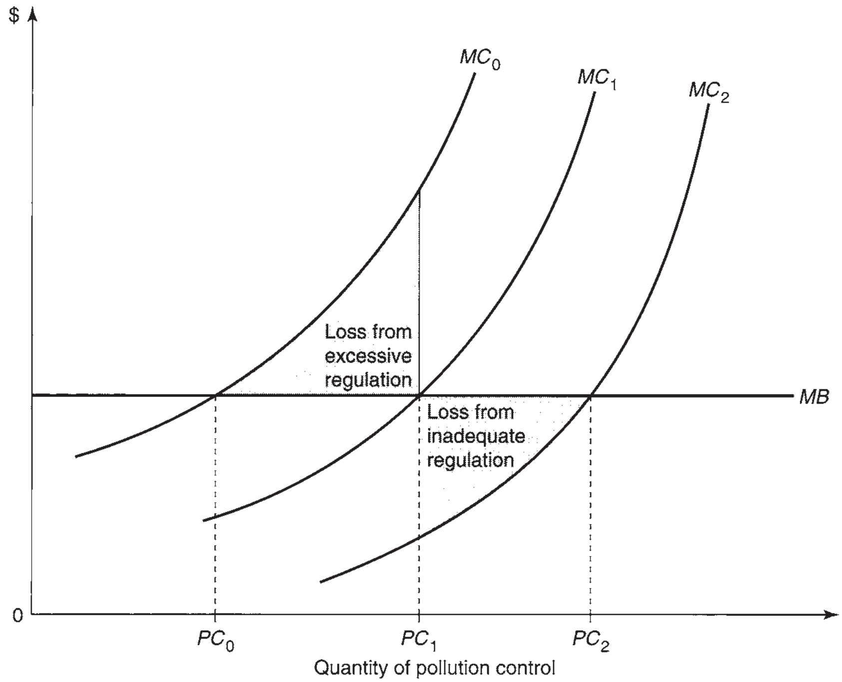

Figure 21.5
Standard Setting with Uncertain Compliance Costs

compliance costs because the technologies needed to attain compliance may not yet have been developed. As is illustrated in figure 21.5, the optimal degree of pollution control ranges from PC_0 in a situation in which the marginal cost curve is given by MC_0 to the intermediate case of PC_1 for a marginal cost curve of MC_1, to a very high level of pollution control at PC_2 for a marginal cost curve MC_2. In situations in which the marginal cost curve can lie between MC_0 and MC_2, the standard consequently could have a very substantial range, depending on how we assess compliance costs.

If we assess these costs incorrectly, then we run the risk of imposing costs that may not be justified. On the one hand, if we set the policy on the basis of a marginal cost curve of MC_1, where the true marginal cost curve is governed by MC_0, then there will be a needless cost imposed by the regulation. The shaded triangle in figure 21.5 that lies above line *MB* gives the value of the excess costs that are incurred because the regulation has been set too stringently. On the other hand, there could also be a competing error in terms of forgone benefits if the standard is set too leniently at PC_1 when the regulation should have been set at PC_2. If the true marginal cost curve is MC_1 and it is believed to be MC_2, there will be a loss in benefits from inadequate regulation. This outcome is illustrated in figure 21.5 by the triangle that lies below line *MB*, between PC_1 and PC_2.

Although setting standards intrinsically must address this problem of uncertain compliance costs, if we were to set a pollution fine equal to the level of the marginal benefit curve in figure 21.5, then firms could pick their quantity of pollution control on a decentralized basis after the pollution had been priced. This approach not only accommodates differences at a particular point in time in terms of technologies, but also accommodates uncertainty regarding the present technology and uncertainty regarding future technological development. If the uncertainty with respect to cost is greater than with respect to benefits, as most regulatory economists believe, then a fee system is preferable to a standards system in such situations.

Pollution Taxes

The operation of a pollution tax approach to promoting optimal pollution control is illustrated in figure 21.6. In particular, suppose that we set the price of pollution equal to the marginal benefits given by the horizontal curve in that diagram. This optimal fine will lead the firm to

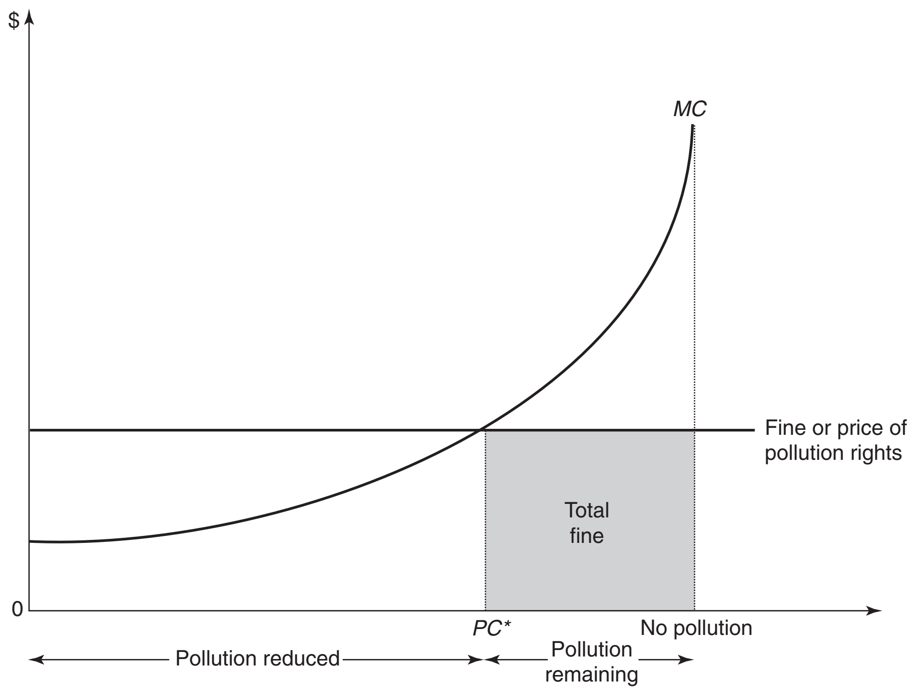

Figure 21.6
Setting the Optimal Pollution Penalty

install the pollution control equipment needed to achieve the level of pollution control given by *PC**. The amount of pollution reduced is indicated on the horizontal axis, as is the amount of pollution remaining. In addition, the shaded portion of figure 21.6 indicates the total fine that firms must pay for their pollution. From the standpoint of short-run efficiency, achieving the pollution control level *PC** through a standard or the fine system is equivalent. From the standpoint of the firms that must comply with this standard, however, the attractiveness of standards is much greater than that of fines. With a standard, the only costs incurred are the compliance costs, whereas under the fine system firms must pay both the compliance costs and the fine for all of the pollution that remains above the optimal control point.

This difference in outcomes raises two classes of issues. The first is whether the fine has any role to play other than simply being a transfer of resources from firms to the citizenry. In terms of the short-run efficiency, the fine does not alter the pollution control outcomes. However, from the standpoint of long-run efficiency, we want all economic actors to pay the full price of their actions.[10] If they do not, the incentive to enter polluting industries will be too great. In effect, society at large will be providing a subsidy to these polluting industries equal to the value of the remaining pollution. Imposition of fines consequently has a constructive role to play from a standpoint of providing correct incentives for entry into the industry and long-run efficiency, even though it will not alter the degree of pollution control by an existing firm.

A second observation with respect to the penalty proposals is that the imposition of costs on firms can be altered to make its impact more similar to that of a standard by making the fine asymmetric. In particular, if we impose a fine only for pollution levels below the standard *PC**, then the purpose of the fine is to bring firms into compliance with the standard. In situations in which firms choose to pay the fine rather than install the necessary control equipment, it may be an index that the original standard was not set appropriately given the firm's particular cost curves. Thus, fines may provide a mechanism to introduce flexibility into an otherwise rigid standard system that does not recognize the heterogeneity in compliance costs that does in fact exist.

Cost Heterogeneity for Water Pollution Control

Figure 21.7 illustrates the considerable variation in compliance costs with water pollution control standards for firms in the tissue paper industry. Although most firms in the industry can comply with the standards for under $6 per ton of effluent, for some very high cost compliers the compliance costs could be four times as great. Rather than have to set standards that reflect the wide differences in compliance costs that may exist, offering the firms the

10. A calculation of the optimal pollution tax to recognize these long-run incentive issues is a nontrivial economic problem. For an analysis of it, see Dennis Carlton and Glenn Loury, "The Limitations of Pigouvian Taxes as a Long-Run Remedy for Externalities," *Quarterly Journal of Economics* 94 (1980): 559–66.

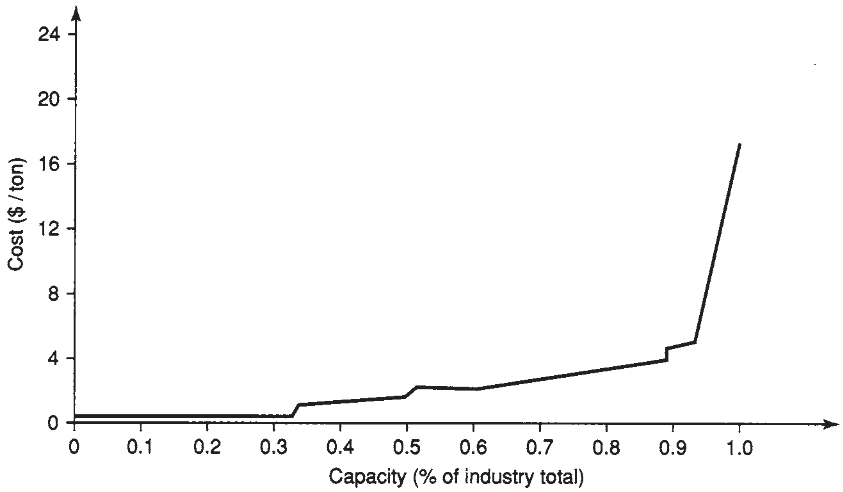

Figure 21.7
Distribution of Water Pollution Control Expenditures in the Tissue Paper Industry
Source: W. Kip Viscusi and Richard Zeckhauser, "Optimal Standards with Incomplete Enforcement," *Public Policy* 26, no. 4 (1979): 443, Figure 2.

option to pay a penalty if they fall short of the standard may be a way to promote efficient pollution control in situations in which there is uncertainty regarding compliance costs. Firms will not have an incentive to misrepresent their compliance costs in such an instance because they must pay the penalty if they cannot meet the standard.

Current Market Trading Policies

Although there has been substantial support for various kinds of fee systems in the economics literature for at least two decades, policymakers have been slow to implement these concepts.[11] Four types of emissions trading options that are available are summarized in table 21.4.[12] In each case firms must apply to the EPA to be permitted to use these mechanisms, and the requirements on such systems are very stringent because there is a continuing suspicion among environmentalists of market outcomes that enable firms to buy their way out of meeting a pollution control standard.

11. It should be emphasized, however, that economists within these administrations have long advocated this approach. Most recently, see the Council of Economic Advisors, *Economic Report of the President* (Washington, D.C.: U.S. Government Printing Office, 1990), chap. 6.

12. For further discussion of these trading options see Crandall, *Controlling Industrial Pollution*, or Hahn and Hester, "Where Did All the Markets Go?"

Table 21.4
Summary of Emissions Trading Activity

Activity	Estimated Number of Internal Transactions	Estimated Number of External Transactions	Estimated Cost Savings (millions)	Environmental Quality Impact
Netting	5,000–12,000	None	$25–$300 in permitting costs; $500–$12,000 in emission control costs	Insignificant in individual cases; probably insignificant in aggregate
Offsets	1,800	200	Probably large, but not easily measured	Probably insignificant
Bubbles:				
Federally approved	40	2	$300	Insignificant
State approved	89	0	$135	Insignificant
Banking	<100	<20	Small	Insignificant

Source: Robert W. Hahn and Gordon L. Hester, "Where Did All the Markets Go? An Analysis of EPA's Emissions Trading Program," *Yale Journal on Regulation* 6, no. 1 (1989): 138. © Copyright 1989 by the *Yale Journal on Regulation*, Box 401A Yale Station, New Haven, CT 06520. Reprinted from volume 6:1 by permission. All rights reserved.

Netting

The first of the mechanisms listed in table 21.4 is netting. Under the netting system a firm can alter its current plant and equipment in a manner that increases the pollution emissions from one source at the plant, provided that it also decreases the emissions from other sources so that the net increase that occurs does not equal that of a major source. These trades cannot take place across firms but are restricted to within firms. Such trades have occurred in several thousand instances. The estimated cost savings from having this flexibility range from $25 million to $300 million in terms of the permitting costs and from $500 million to $12 billion in terms of emission control costs. For this as well as for the other market trading systems listed, the adverse environmental effect is believed to be minimal.

Offsets

The second most frequent market trading activity is offsets. Under an offset option, firms will be permitted to construct new facilities in a part of the country that exceeds the EPA's maximum permissible level of pollutants. However, before the company can build a plant in such an area, it must purchase pollution offsets from some existing facility in that area that provides for more than an equivalent reduction of the same pollutant. Moreover, the party selling these offsets must already be in compliance with EPA standards. Although there were 1,800 offset purchases by the mid-1980s, for the most part these involved internal market trades rather than external transactions.

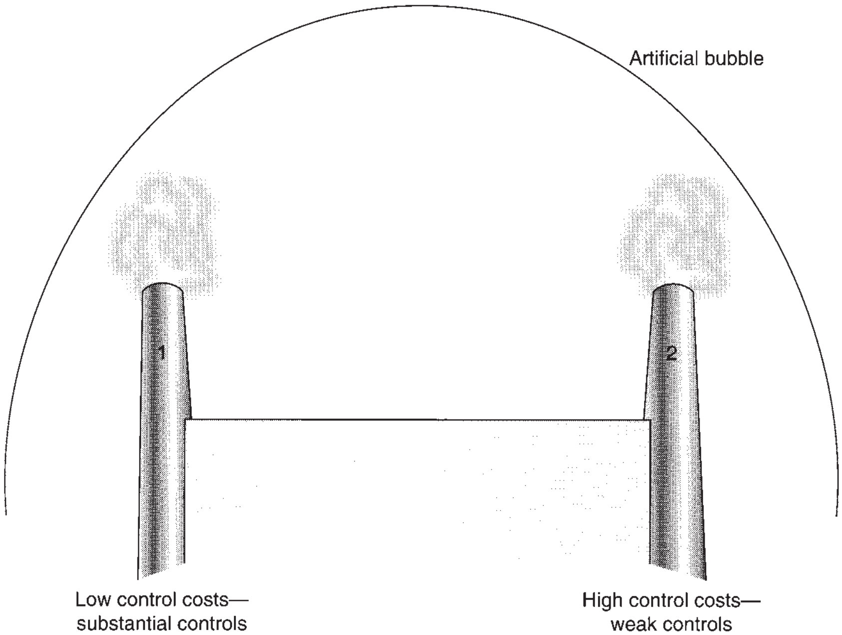

Figure 21.8
EPA Bubble Policy Standard for Total Emissions

Bubbles

The third policy option was introduced with great fanfare in December 1989 by the Carter administration. Under the bubble concept a firm does not have to meet compliance requirements for every particular emissions source at a firm. Ordinarily, each smokestack would have to comply with a particular standard. Instead, the firm can envision the plant as if it has been surrounded by an artificial bubble. The compliance task then becomes that of restricting the total emissions that will emerge from this bubble to a particular level. This option enables the firm to have some flexibility in terms of what sources it will choose to control. If there are two smokestacks, for example, as in the case of figure 21.8, the firm will choose to achieve the greatest pollution reduction from smokestack 1, as these costs will be lower than for pollution reduction in smokestack 2. There have been over a hundred such bubbles approved by the EPA, with cost savings to DuPont and other firms totaling $435 million.

Banking

The final option is banking. Under the banking policy, firms in compliance with their standards can store pollution rights over time, and then use these rights in the future as an offset against future pollution. The use of this policy option has been fairly infrequent.

The Future of Market Approaches

A major policy shift occurred in the 1990s. President Bush, for example, declared a commitment to increase reliance on market trading options,[13] and some programs of this type were implemented. The EPA has not, however, replaced the thrust of its policy standards effort with a tradable pollution permit system.

Nevertheless, permits have attractive economic features, as firms with the highest compliance costs can purchase them, thus fostering an efficient degree of control of pollution.

The first advantage of tradable pollution rights is that they enable the EPA to equalize the opportunity costs of pollution control. Second, they encourage innovations to decrease pollution, whereas a rigid standard only encourages a firm to meet the standard, not to go any further. Pollution rights systems also create less uncertainty for firms that must make fixed capital investments. Changing technology-based standards over time poses a risk that a firm's capital investments will become obsolete.

The disadvantage of pollution rights is that we must set the number of such rights. Establishing the quantity of such rights is not too dissimilar from setting an aggregate pollution level. It requires a similar kind of information, and it probably relies on more imperfect forms of information than would establishing a penalty scheme. However, a fee system for all pollution generated imposes such substantial costs that there is currently political opposition to this approach.

Other criticisms of pollution rights systems pertain to whether the market participants are really trading a uniform good. The impact of pollution depends on the character of the pollutants, the stack height, and similar idiosyncratic factors. These pollutants also may interact with other pollutants in the area so that their consequences may differ. There also may be decreased ability to enforce marketable permit systems, as compared with a situation where the EPA mandates a particular technology for which officials can readily verify compliance. This concern may be of less consequence because many EPA standards, such as its water discharge requirements, are in terms of discharge amounts that must be monitored and reported on a monthly basis to the EPA.

The final concern that has been raised relates to market power. Will some large players, such as public utilities, buy up all of the pollution rights? Thus far, such concerns have not been of practical consequences.

By far the greatest resistance to the marketable permit scheme is the general suspicion of markets among noneconomists. Their counterargument often takes the following form: "Should the government also sell rights to murder?" A more appropriate question to use is, which policy approach will be most effective in reducing pollution at less cost? Although the

13. For a discussion of the position of the Bush administration, see the *1990 Economic Report of the President*, chap. 6.

EPA has attempted to increase their salability by labeling such systems as ones in which firms sell pollution reduction credits rather than purchase pollution rights, these efforts continue to remain limited and fairly experimental in nature.

Global Warming and Irreversible Environmental Effects

Whereas the environmental policies of the 1970s focused primarily on conventional air and water pollutants, and efforts of the 1980s turned to toxic chemicals and hazardous waste, attention in the 1990s shifted to the long-term character of Earth's climate.

Chief among these concerns is global warming. The accumulation of carbon dioxide and other trace gases in Earth's atmosphere in effect has created a greenhouse around Earth. This change in Earth's atmosphere is expected to produce global warming from 1990 to 2100 on the order of one to six degrees Celsius, or two to ten degrees Fahrenheit. Scientists continue to debate the magnitude and timing of the effect. Some global warming is inevitable irrespective of current efforts to impose environmental controls because of the irreversible nature of the generation of the greenhouse gases. We have already taken the actions that will harm our future environment. The extent of the future warming is uncertain because of both the substantial uncertainty regarding climatological models and the uncertainty regarding factors such as population growth and our pollution control efforts in the coming decades.

Even more problematic is the effect that global warming will have on society. Although the temperature will rise by several degrees, for northern regions this trend will be a benefit, and for southern regions it will generally be a disadvantage. The warming in the winter will be beneficial and will occur to a greater extent than the warming in the summer, which will have an adverse effect. Russia and Canada may benefit from longer growing seasons. Some have even questioned the desirability of a temperature change. Will global warming, for example, be tantamount to getting on a plane in Boston and arriving in Los Angeles? U.S. retirement patterns suggest that warmer weather may in fact be preferable. Change of any kind will necessarily lead to the imposition of some adjustment costs. Climatologists also predict that there will be an increase in damage from natural disasters such as hurricanes. The average sea level will rise, and there may be droughts in interior lands.

Assessing the Merits of Global Warming Policies

Although a precise assessment of the optimal policy relating to global warming is not possible, one can frame the issues and obtain a sense of the types of concerns that are being addressed within the context of what will prove to be an ongoing policy debate.[14]

14. This discussion of the greenhouse effect, particularly the graphical exposition, is based most directly on the article by William D. Nordhaus, "Global Warming: Slowing the Greenhouse Express," in Henry Aaron, ed., *Setting National Priorities* (Washington, D.C.: Brookings Institution, 1990), pp. 185–211.

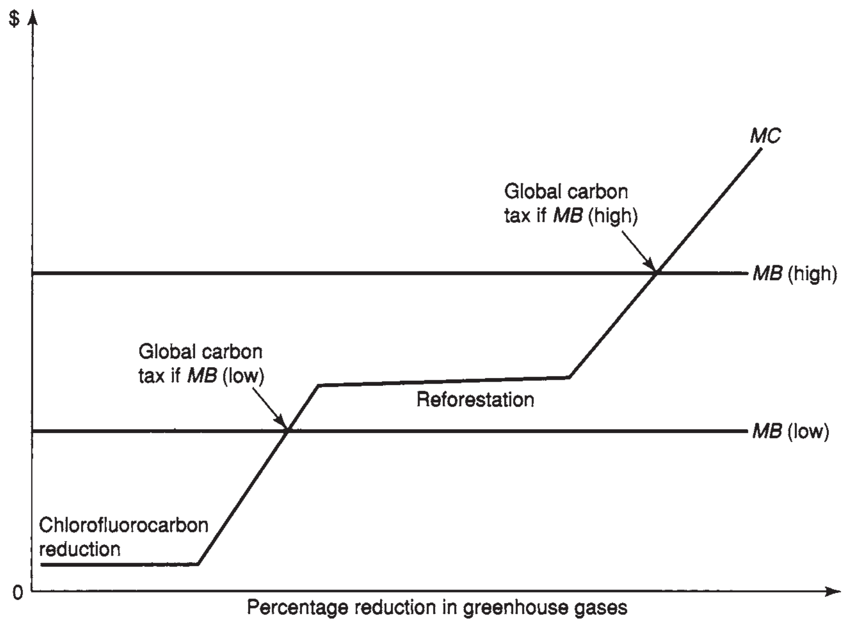

Figure 21.9
Establishing the Optimal Global Warming Policy

Figure 21.9 sketches the marginal cost curves for addressing global warming by controlling the emission of greenhouse gases. This has been the approach taken by economists such as William D. Nordhaus.[15] The first of the three policy options is reducing chlorofluorocarbons, such as bans on the use of freon in refrigerators. The second policy option listed is the imposition of a global carbon tax, which will penalize usage of gasoline or coal to produce energy, thus recognizing the environmental externalities they impose. The third policy option listed is reforestation. Additional forests serve to reduce the global warming problem by converting carbon dioxide into oxygen.

Also shown in figure 21.9 are two marginal benefit curves, one designated "*MB* (low)" and another designated "*MB* (high)." The purpose of illustrating the two curves is to indicate how the policy might change depending on our uncertainty regarding the ultimate societal implications that global warming will have.

What is clear from this figure is that even in the case of the low marginal benefit curve, some actions are clearly worthwhile. Elimination of chlorofluorocarbons and the imposition of some global carbon tax is clearly efficient, even in the case in which the low-benefit

15. Nordhaus, "Global Warming."

scenario prevails. If benefits are at a higher level, then policies of reforestation and a steeper global carbon tax are also worthwhile.

Whereas in most environmental contexts it is the marginal costs that are more uncertain than the marginal benefits, in this long-run environmental context, benefits also pose substantial uncertainty. This uncertainty is at a very fundamental level. There is even a debate over whether on balance, global warming will be beneficial or adverse to our economy. However, even at the very low level of costs that are assumed in figure 21.9, some policy options such as chlorofluorocarbon reduction are optimal.

How Should We React to Uncertainty?

Although further study to resolve these uncertainties is clearly a desirable policy alternative, if we were in a situation in which we had to take an action today, an economic issue arises as to whether the substantial uncertainties imply that we should err on the side of caution or err on the side of reckless abandon.

As we continue to study the climate change issue, there will also be calls for policy action. One approach that has gained widespread support is the "no regrets" option. We should clearly adopt policies, such as energy conservation, that would be desirable irrespective of what we ultimately learn about the implications of climate change. Whether we should go beyond the "no regrets" policy is more controversial.

Some insight into resolving this problem is provided by examining the classic irreversible development decision situation.[16] Figure 21.10 illustrates the basic irreversible investment paradigm. A developer must choose the degree of current development, where the benefits and costs of this development at the present time are known. There is, however, uncertainty regarding the degree to which environmental preservation will be valued in the future. There is some probability p that the preservation will have a high value, and there is some probability $1 - p$ that the preservation will have the same value that it does at the present time. In such a situation of uncertainty, how should one choose the extent to which one will develop the scarce resource, such as conversion of a national forest into a shopping center and suburbs?

In general, the answer is that one should err on the side of underdevelopment in such situations. Moreover, the greater the probability that preservation will have a high value and the greater the increase that this value will be, the more one should alter one's current decision from what one would select based on a myopic assessment of the benefits and costs of the development policy.

This principle for underdevelopment does not generalize to every situation in which there are irreversible decisions to be made. For example, companies installing pollution control

16. An early exposition of the irreversible environmental choice problem appears in Kenneth J. Arrow and Anthony C. Fisher, "Preservation, Uncertainty, and Irreversibility," *Quarterly Journal of Economics* 88 (1974): 312–19.

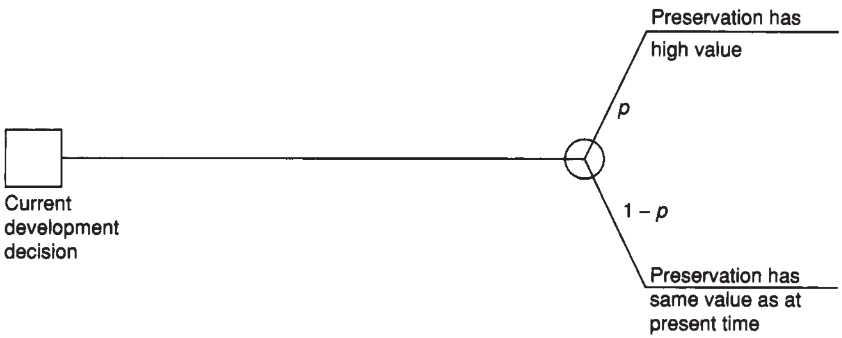

Figure 21.10
Irreversible Environmental Decisions

equipment might rationally choose to overinvest in such equipment if they expect the standard to be tightened in the future. Much depends on the character of the problem and the nature of the uncertainty. However, for problems like global warming, where the main uncertainty is with respect to the potential increase in the benefits of controls above current levels based on the current benefits associated with pollution control, the general policy maxim is that conservatism is the best policy.

Moreover, it is noteworthy that this conservatism arises wholly apart from the presence of any risk aversion. Society does not choose to err on the side of caution because we are unwilling to engage in risks. Rather, the bias arises because the expected payoffs from development in the future may be much less than they are today, and we should take this possible change in values into account.

Multiperson Decisions and Group Externalities

Externality problems become particularly complex within the context of group decisions. In the situation of an individual firm and the citizenry, one has to worry only about the actions of one economic actor. However, in actual practice many of the most important externalities arise from the decentralized decisions of a variety of actors. In these contexts, some coordination mechanism is often desirable to promote behavior that will be collectively beneficial to society.

The Prisoner's Dilemma

The standard situation in bargaining theory where uncoordinated action gives rise to an inferior outcome is that of the Prisoner's Dilemma. Suppose that there are two partners in crime, each of whom has been captured by the police. The prisoners are held separately, preventing

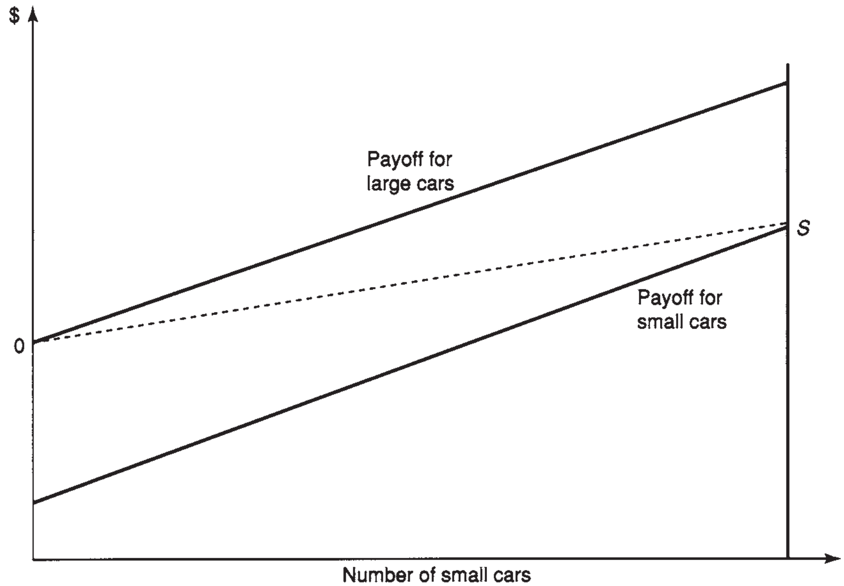

Figure 21.11
The Multiperson Prisoner's Dilemma

cooperation. The police offer to lighten each prisoner's sentence if he will incriminate the other. The prisoner must make a risky decision, based on what he believes the other is most likely to do. Following the standard scenario, the prisoners each choose their preferred strategy of talking to the police. Talking is a dominant strategy for each party, given any particular behavior on the part of the other prisoner. However, if both of the prisoners had agreed not to talk, they would have been better off than they will be after they both incriminate one another. The outcome is consequently Pareto inferior (that is, each gets a lower-valued payoff) when compared to the situation in which both of them remained silent.

The *N*-Person Prisoner's Dilemma

A variety of social situations also arise in which there are incentives for individual behavior that do not lead to optimal group outcomes. Figure 21.11 illustrates a multiperson Prisoner's Dilemma, using a methodology developed by Thomas C. Schelling, where the particular context being considered is the purchase of a large or small car.[17] We will suppose for concreteness that consumers prefer large cars to small cars. Thus, for any given number of small

17. The diagrammatic exposition that follows is based on the innovative work of Thomas C. Schelling, *Micromotives and Macrobehavior* (New York: W.W. Norton, 1978).

cars on the market along the horizontal axis, the consumer's payoff received for using a large car exceeds that for a small car. The result is that because everybody has a dominant strategy to purchase a large car, we end up at the equilibrium, 0. This equilibrium is not a social optimum, however. In particular, if we could constrain everyone to purchase a small car, we could reach the outcome at point *S*, which has a higher value than 0. The reason why some constraint is needed is that this is not a stable equilibrium. Any individual driver has an incentive to break away and purchase a large car, leading to an unraveling until we reach the stable equilibrium at 0. Thus, some government regulation is required.

Applications of the Prisoner's Dilemma

Group externalities such as this arise in a variety of contexts. In international whaling, exercising some restraint in terms of the number of whales that are caught in any year will maximize the value of the whaling population. Thus, even if one were simply concerned with the commercial value of the whales, some limitation on whaling is optimal. However, from the standpoint of the individual fisherman it is always optimal to catch as many whales as you can. If all of the whaling vessels follow their dominant strategy, as most of them have, the result is that the whaling population will be overfished and that we will have a dwindling number of whales. In this instance, the optimal strategy is to provide for some restraint but not a complete abolition of whaling activities. Achieving this moderation in the degree of whaling has proven to be a long-term international regulatory problem.

The international whaling example has proven to be more than a hypothetical case. In 1994 the United States government proposed that the Georges Bank fishing area off New England be closed so that the species could revive. This fishing ground, which had formerly been one of the richest in the Atlantic Ocean, was the source of fish such as cod and haddock. This fishing area also served as the principal source of livelihood for fishing villages in New England, such as Gloucester. Restraints on fishing proved to be ineffective, which led the federal government in 1994 to propose the more drastic step of closing these fishing grounds altogether so that the fishing stocks could revive. Unfortunately, the difficulty in monitoring and enforcing appropriate fishing restrictions has proven to be so great that the government was led to a much more costly and disruptive regulatory policy option that has led to the abandonment of a fishing fleet and the shutdown of a major industry throughout much of the New England area.

Similar classes of issues arise within the context of vaccinations. If a critical mass in society has received an inoculation, it is not optimal to get vaccinated because the risk of contracting the disease will generally be much less than the expected health loss due to an adverse reaction to the vaccine. We clearly need some coordinating mechanism to ensure that a sufficient portion of the population has received the vaccination, but given the fact that society has established such a vaccination requirement, each of us has an incentive to be exempted from the vaccination.

Similarly, home owners who are doing battle against Japanese beetles will be able to diminish their efforts if all of their neighbors use insecticides. However, it is essential to establish a sufficiently broad insecticide use to control the beetle population. The initial insecticide user may obtain little benefit unless a sufficient number of his neighbors also use the insecticides. At low and high levels of community-wide insecticide use, the individual incentive to use insecticides will be lacking. There is no voluntary incentive for an unassisted market process to begin generating the decentralized decisions needed to reach the social optimum.

The general result that pertains in situations in which there are group externalities is that some form of coordination is often worthwhile. This coordination often takes the form of explicit regulations. Hockey players are required to wear helmets, traffic rules require that we drive on the right side of the road, and daylight saving requirements establish uniform changes in the time schedule for everyone. Individually, the payoff of shifting to daylight saving time is quite low if no one else in society shifts, but if we can all coordinate our actions, we will all be better off.

The Enforcement and Performance of Environmental Regulation

Enforcement Options and Consequences

The promulgation of regulations does not ensure that firms will comply with them. As a result, the EPA and other regulatory agencies couple the issuance of regulations with vigorous enforcement efforts. In the case of major sources of air and water pollution, the EPA attempts to inspect the emissions source at least once per year. Moreover, in the case of water pollution discharges, the EPA requires by law that the firms submit a record of the nature of the discharge to EPA and that each firm report its compliance status with the pollution permit that it has been given.

The enforcement task with respect to conventional pollutants is generally viewed as being the simplest. Next in terms of the degree of difficulty is enforcement with respect to toxic chemicals. These chemicals are often more difficult to monitor than are conventional pollutants because of specific chemical testing that must be undertaken.

The nature of the source of the pollution also affects the feasibility of effective enforcement. Hazards that arise on a decentralized basis, such as toxic wastes, radon in consumers' homes, and asbestos in buildings, often impose substantial enforcement problems because of the large number of pollution sources involved and, in the case of toxic chemical dumping, the difficulty of monitoring the party responsible.

Enforcement of environmental regulations pertaining to chemicals and pesticides varies in effectiveness depending on the nature of the regulation. The process of screening chemicals and regulating the chemicals that are being sold and used commercially is quite effective because of the ability to monitor mass-produced consumer goods. The EPA also can readily monitor the hazard warnings attached to these products. Much more difficult to monitor is the manner in which the products are used. The disposal of chemical containers and the dilution of insecticides are among the decentralized activities that pose almost insurmountable problems. The best that the EPA can achieve in these instances is to provide risk information to foster the appropriate safety-enhancing action on the part of the product users.

In these various inspection contexts, the EPA has several enforcement tools that it can use. Not all of these involve fines, but they do impose costs of various kinds on the affected firms. The EPA can inspect a firm. It can request that the firm provide data to it. It can send the firm letters, or it can meet with the firm's managers to discuss pollution control problems. Most of the EPA's contacts with firms are of this character.

In terms of sanctions, there are two classes of financial penalties that can be levied. The first consists of administrative penalties that are usually modest in size and limited in terms of the circumstances in which they can be levied. The main sanction that the EPA has is not the penalties that it can assess, but rather the penalties that can be assessed through prosecution of the polluter by the U.S. Department of Justice. In severe, flagrant, or persistent cases of violations of EPA standards, the EPA frequently refers the case to the U.S. Department of Justice for civil or criminal prosecution. The costs associated with the prospective litigation, as well as the possibility that substantial fines may be imposed, often provides a compelling enforcement sanction.

Hazardous Wastes

Public opinion polls typically rank the cleanup of hazardous wastes as one of the most important environmental problems. Beginning in the 1980s, the U.S. EPA became much more concerned with toxic substances and hazardous wastes. This cleanup effort, knows as the Superfund Program, has sought to eliminate the risks posed by these chemical waste sites, which chiefly consisted of cancer hazards to the surrounding population.

What is perhaps most striking about this environmental policy area is the substantial mismatch between the public's concern with the environmental risks and the efficacy of the environmental cleanup effort. The source of the difficulty can be traced in part to the legislative mandates under which the EPA operates. There is no stipulation that the EPA balance the benefits to surrounding populations against the costs of cleanup, but instead the focus is on risk alone. Moreover, since the cleanup costs will be borne largely by the potentially responsible parties, which are private firms rather than the citizens affected by the hazard, there will be considerable political pressure for uncompromising cleanup remedies, such as removing the contaminated waste from the site and incinerating it.

The policy trigger for cleanup is that a site must be cleaned up if it poses a potential lifetime cancer risk of at least one in 10,000, and cleanup is at the EPA's discretion provided the lifetime risk is at one in 1,000,000 or more. Recall from table 19.3 that many routine daily activities pose a risk from a single event of one chance in a million. Eating forty tablespoons of peanut butter, traveling ten miles by bicycle, and smoking 1.4 cigarettes all pose a one-in-a-million fatality risk. If one were to undertake such activities over one's lifetime rather than in a single episode, then the overall risk would be even greater and would dwarf that posed by many hazardous waste sites that have been targeted for cleanup.

Before deciding on the level of the hazard, the EPA must first ascertain who lives near the site and will be exposed to the risk. In addition to examining current populations, the EPA assumes there is a risk if there is some potential chance that a future population could be exposed to the risk, even if such a chance is unlikely. Supreme Court Justice Stephen Breyer, for example, noted that at one Superfund site involving a case in which he ruled, a modest cleanup effort could make the dirt at the site clean enough so that children could eat the dirt for 70 days per year.[18] However, the EPA spent an additional $9.3 million to clean up the site so that children would be able to eat the dirt without risk for up to 245 days per year. What was noteworthy about the site is that no children lived near the site, which was a swamp. Similar unrealistic assumptions may affect the risk estimates at other sites, such as the North Carolina Superfund site at which it is assumed that a factory will be built in the future and that during their lunch break workers will swim in a nearby creek, exposing them to the contaminated water.

For the EPA to find a risk there need not be a population actually exposed to the hazardous waste site. If a person could potentially move to that area and have some potential for exposure in the future, then the EPA will treat the risk as being just as consequential as would be the case if there were a large exposed population. The net result is that whether there are in fact exposed populations plays no role in triggering an EPA cleanup, a fact which will have important consequences for the efficacy of cleanups.

Note that the trigger for cleanup is whether a real or hypothetically exposed future individual has reached a critical lifetime risk threshold. This focus on individual risks consequently ignores the size of the total population at risk. Densely populated areas in close proximity to a Superfund site receive the same policy weight as a single hypothetically exposed future individual. Because minority populations tend to be disproportionately concentrated near hazardous waste sites, the practical effect of this approach is to give inadequate weight to such sites in the priority setting process. In contrast, consideration of economic benefits in terms of the expected number of cancer cases prevented would give greater weight to these highly populated sites.

In calculating the individual cancer risk at a site, the EPA uses conservative risk estimates. To see how conservative biases enter the analysis, it is useful to consider the components of the calculation. Lifetime excess cancer risk is given by

18. See Stephen Breyer, *Breaking the Vicious Circle: Toward Effective Risk Regulation* (Cambridge, Mass.: Harvard University Press, 1993).

$$\frac{\begin{pmatrix}\text{Exposure}\\\text{Duration}\end{pmatrix}\times\begin{pmatrix}\text{Exposure}\\\text{Frequency}\end{pmatrix}\times\begin{pmatrix}\text{Ingestion}\\\text{Rate}\end{pmatrix}\times\begin{pmatrix}\text{Contaminant}\\\text{Concentration}\end{pmatrix}\times(\text{Toxicity})}{\text{Body Weight}\times\text{Averaging Time}}.$$

The denominator terms are not controversial, as the EPA uses an average body weight assumption, while the averaging time component simply controls for the proper units in the calculation. The key components are the five elements in the numerator of the calculation. For each of these individual variables, the EPA uses a conservative assumption, typically the 95th percentile of the distribution. Thus, there is only one chance in 20 that the exposure duration could be as great as the assumed value. By using such upper bound values for each of the five parameters in the numerator, the result is a cascading of conservatism bias so that the resulting estimate is well beyond the 99.99th percentile of the true risk distribution.

Economists instead would generally recommend calculating the expected number of cancer cases based on the mean values of the risk. If there is political support for being very protective in the cleanup actions, that concern can be expressed through a high unit benefit value on the cancer cases prevented. The current EPA practice distorts regulatory priorities by shifting the policy emphasis toward dimly understood risks that may pose no threat to existing populations.

What will be the consequence of ignoring cleanup costs, mismeasuring the magnitude of the risk, and failing to account for the size of exposed populations? One would expect hazardous waste cleanup efforts to be very ineffective. Table 21.5 summarizes the cost effectiveness of various Superfund cleanup efforts measured in terms of the cost per expected case of cancer prevented. After ranking the sites from the most cost-effective to the least cost-effective, James T. Hamilton and W. Kip Viscusi calculated the cost-effectiveness at these

Table 21.5
Summary of Superfund Cost-Effectiveness*

Percentage of Remediation Expenditures, Ranked by Cancer Cost Effectiveness	Cumulative Percentage of Total Expected Cancer Cases Averted	Marginal Cost per Cancer Case Averted ($ millions)
5	99.47	145
25	99.86	1,107
50	99.96	6,442
75	99.97	28,257
95	99.98	241,058

* Using the following assumptions: average exposure concentrations and intake parameters, 3 percent discount rate and no growth factors for cost, 3 percent discount rate for cancers, and a ten-year latency period for the development of cancer.

Source: James T. Hamilton and W. Kip Viscusi, *Calculating Risks?: The Spatial and Political Dimensions of Hazardous Waste Policy* (Cambridge, Mass.: MIT Press, 1999), Table 5.6.

different levels.[19] U.S. Supreme Court Justice Stephen Breyer and others have hypothesized that there is a 90–10 principle, whereby agencies expend 90 percent of their resources to clean up the last 10 percent of the risk. In the case of the Superfund Program, the drop-off in efficacy is much more stark. The 5 percent of Superfund cleanup efforts that are the most effective address the hazards that will eliminate 99 percent of the human health risks. As indicated by the statistics in table 21.5, less than 1 percent of the cancer cases are eliminated for the least effective 95 percent of the expenditures.

The drop-off in cost-effectiveness is enormous. By the fifth percentile the cost per case of cancer prevented is $145 million, and the median Superfund cleanup expenditure prevents cases of cancer at a cost of $6.4 billion per case. Even these estimates, high as they are, understate the actual cost per case of cancer prevented because they are based on conservative EPA health risk assumptions and conservative assumptions about the degree to which populations will in fact be exposed to the risk.

If EPA policy decisions are not responsive to economic efficiency, what is it that drives them? The factors that appear to be most influential are political. The voting rate for the county, for example, is particularly influential in determining whether a site is cleaned up and the stringency of cleanup.

The cleanup of hazardous waste has also been the focal point of the environmental equity movement, whereby many have suggested that minorities are disproportionately exposed to hazardous waste. Much of this problem can be traced to the fact that minorities have less political leverage than do more affluent white populations. It is also noteworthy that targeting cleanups based on the economic efficiency concerns would do more to advance environmental equity than the current politically based process. Minority sites have higher benefit-cost ratios, or lower cost levels per case of cancer prevented. Economic efficiency concerns are in fact supportive of environmental equity by making cleanup of hazardous wastes equally meritorious, irrespective of the political clout of the affected population.

Contingent Valuation for the *Exxon Valdez* Oil Spill

One of the most controversial areas on the frontier of environmental economics is the use of contingent valuation techniques to value environmental damages. Under this approach researchers design survey questions to elicit the values that people attach to scarce environmental resources for which no good market values exist. The debate over the soundness of the technique reached its peak with respect to the *Exxon Valdez* oil spill, for which damage levels in the billions of dollars raised the stakes of the economic debate over this

19. For an overview of these issues, see W. Kip Viscusi and James T. Hamilton, "Are Risk Regulators Rational? Evidence from Hazardous Waste Cleanup Decisions," *American Economic Review* 89 no. 4 (September 1999): 1010–27, and for a fuller description, see James T. Hamilton and W. Kip Viscusi, *Calculating Risks?: The Spatial and Political Dimensions of Hazardous Waste Policy* (Cambridge, Mass.: MIT Press, 1999).

methodology considerably. Calculating the losses to fishermen, the costs of cleaning up the shoreline, and related financial allocations is fairly straightforward. However, how should one calculate the environmental damages suffered by the entire U.S. citizenry because of the *Exxon Valdez* oil spill? Controversies over the use of contingent valuation continue to rage and have led to a government report that sought to provide some guidance; contributors to the report included two Nobel laureates in economics, Kenneth Arrow and Robert Solow.[20]

To get some sense of the nature of this enterprise, consider the contingent valuation study undertaken by the state of Alaska as part of the litigation over the environmental damage. The implications of this survey were not simply of academic interest but served as critical inputs to the litigation process and would have played a substantial role in the court deliberations had the case not been settled out of court. The U.S. Department of Justice also undertook a series of contingent valuation studies, and the Exxon Corporation solicited numerous economists as well to assess the damages and to comment on the validity of the other parties' assessments.

The survey developed for the state of Alaska reflects the general character of the contingent valuation approach.[21] The objective was to determine how much the public should be compensated to offset the loss they suffered because of the spill. After asking respondents about their general views on a variety of policy issues, the survey asked respondents if they were acquainted with the *Exxon Valdez* oil spill, which occurred in Prince William Sound, Alaska, in March 1989. As a result of this incident, 11 million gallons of crude oil spilled into the water. At that point the respondents indicate whether they recalled hearing of the *Exxon Valdez* oil spill. Although the survey proceeds regardless of whether they had heard of this spill, some debate remains as to whether the valuations should matter if people have not heard of the spill and suffered a welfare loss. The alternative perspective is that the value assigned should be based on what it would be if people had full information regarding it.

The survey then undertook a substantial educational effort regarding the character of the spill. Respondents considered maps and photos indicating the area on Prince William Sound that was contaminated by the spill. In addition, they were shown photos of wildlife in the area, including sea ducks, murres, seagulls, and sea otters. After viewing a picture of the tanker sailing through the sound, respondents then considered a variety of maps indicating the extent of the spill, which affected about 1,000 miles of shoreline. They also viewed a series of photos showing the oiled shore and the cleanup activity. Notwithstanding these

20. For discussion of the National Oceanic and Atmospheric Administration report on natural resource damages, see "Natural Resource Damage Assessments under the Oil Pollution Act of 1990," *Federal Register* 58, no. 10 (January 15, 1993): 4601–14.

21. The following discussion will be based on the *Exxon Valdez* C.V. Survey Questionnaire, National Opinion Survey Main Interview Questionnaire, administered for the state of Alaska by Westat. The principal researchers included Richard Carson, Robert Mitchell, and other economists.

efforts, there was a significant effect on wildlife. The survey informed the respondents that "22,600 dead birds were found" and that scientists estimate that "the total number of birds killed by the spill is between 75,000 and 150,000." This death total included 5,000 bald eagles. Respondents also learned that 580 otters and 100 seals were killed by the spill. They received information about how long it would take for these populations to return to normal. One of the critiques of contingent valuation studies is that respondents may not be sensitive to whether they have learned that 100 birds or 10,000 birds have been killed, as they may give the same willingness-to-pay answer to prevent either incident.

The unresponsiveness of the willingness-to-pay values to the extent of the environmental damage has been designated the "embedding" problem. It may be that respondents are not in fact expressing their preference for the particular environmental good specified in the survey but rather are simply voicing support for the environment more generally. Incorporating a detailed series of rationality tests in a survey can help test for whether this potential problem is in fact pertinent.

After learning of the damage caused by the *Exxon Valdez* spill, respondents are asked how much they would be willing to pay for an escort ship policy that would prevent such spills from occurring over the next ten years. Without such a program, there would be one spill expected on average, according to the survey. The price mechanism would be a one-time tax on both oil companies and on households, where the household tax would be levied through higher federal income taxes. Respondents then considered a variety of possible costs for the program, such as $60 per household in higher taxes, and were asked whether they would vote for such an effort. The median response for the households was a willingness to pay for the escort program on the order of $49 per household, or a total value for the United States of $2.8 billion. Some critics might think that this willingness to pay is inordinately large for a comparatively modest escort program.

Although the approach taken in the Alaskan survey is one possible survey methodology, there are others as well. Surveys can differ considerably with respect to the level of detail that is presented to the respondents about the spill. Moreover, how the effects of the spill are presented can be influential. If the respondents were to consider the percentage of birds in the local population that were affected as opposed to the absolute number, their view might be different. Moreover, there are a variety of policy contexts that could be used. One might, for example, ask how much one would be willing to pay to reverse the effects of the spill through an ambitious cleanup operation. For prospective scenarios, there is a wide range of policy options that one could suggest to respondents as being potentially effective. Moreover, there are payment mechanisms other than higher federal taxes that could come into play, such as higher gasoline prices. What is essential, however, is that the payment mechanism be credible and that respondents indicate their true willingness to pay for prevention efforts, rather than simply naming some hypothetical dollar figure to impress an interviewer who has spent half an hour showing them pictures of dead birds and sullied shorelines. Because no reliable market prices exist for many natural resources and because these valuations are critical both in court cases and for policy decisions, the controversies over how outcomes should be valued will continue to rage for many years to come.

The Senior Discount for the Value of Life

In 2003 the EPA generated a national controversy with respect to the value it applied to the reduced risks for senior citizens. The context of this controversy was a proposed air pollution policy called the Clear Skies Initiative. With many air pollution efforts, the benefits are concentrated at the tails of the population, as children and the elderly are most at risk. Should the same benefit value be applied to each age group? The elderly have a much shorter life expectancy at risk, so some age adjustment might seem reasonable. Based on willingness-to-pay survey results, the EPA applied a 37 percent senior discount to their benefits, leading to an outcry from senior citizen groups such as AARP: "Seniors on sale, 37% off." The EPA administrator resigned shortly after this controversy emerged.

Table 21.6 summarizes the reduced fatalities and the associated benefits. There were two different benefit estimates, one based on long-term exposures and one based on short-term exposures. If decreased expected fatalities are valued using the EPA's uniform value of $6.1 million, then one obtains the benefit estimate in the constant value of life column. The EPA also showed alternative benefit estimates adopting a 37 percent senior discount, and this change decreases benefits by $13.5 billion based on long-term exposures and by $7.2 billion

Table 21.6
Age Group Effects on Clear Skies Initiative Benefits

		Benefits of Reduced Mortality ($ billions undiscounted)		
Age Group	Reduced Annual Fatalities in 2010	Constant Value of Life	Value with Senior Adjusted	Consumption-Adjusted Value of Life
Base Estimates—Long-Term Exposure:				
Adults, 18–64	1,900	11.6	11.6	11.6
Adults, 65 and older	6,000	36.6	23.1	37.1
Alternative Estimate—Short-Term Exposure:				
Children, 0–17	30	0.2	0.2	0.1
Adults, 18–64	1,100	6.7	6.7	6.7
Adults, 65 and older	3,600	21.9	14.7	22.3

Note: The reduced annual fatalities figures are from the U.S. EPA's *Technical Addendum: Methodologies for the Benefit Analysis of the Clear Skies Initiative* (Washington, D.C.: U.S. Environmental Protection Agency, 2003), Table 16. The 37 percent senior discount is from the U.S. EPA's *Technical Addendum: Methodologies for the Benefit Analysis of the Clear Skies Initiative* (Washington, D.C.: U.S. Environmental Protection Agency, 2002), p. 35, and the $6.1 million figure per life is from the U.S. EPA's *Technical Addendum: Methodologies for the Benefit Analysis of the Clear Skies Initiative* (Washington, D.C.: U.S. Environmental Protection Agency, 2003), p. 26. Estimates in the final column are drawn from Thomas J. Kniesner, W. Kip Viscusi, and James Ziliak, "Life-Cycle Consumption and the Age-Adjusted Value of Life," Harvard Olin Working Paper No. 459 (2004).

based on short-term exposures. The stakes involved in terms of the level of benefits were quite substantial.

To address this sensitive issue, it is useful to go back to first principles. The appropriate benefit value is the willingness to pay for the risk reduction. This amount could decline for those with a shorter life expectancy, but it also might remain high because of increases in wealth with age. What matters is this willingness-to-pay value, not the quantity of life per se. On a theoretical basis, the value of statistical life should rise and then eventually fall over the life cycle. The main open question is empirical. How much does this value decline for those with short life expectancies?

The empirical evidence is still emerging. One survey of respondents in the United Kingdom indicated that the willingness to pay dropped by 37 percent for senior citizens, while a survey in Canada showed a comparatively flat relationship with age. Labor market evidence on workers' value of statistical life is consistent with the inverted U-shaped relationship, but estimates differ in terms of the steepness of this decline at the upper end of the age distribution. One set of estimates that account for changes in the level of consumption over time indicates that the value of statistical life for those in their sixties is below their peak lifetime value, but is still above comparable values for people in their twenties and thirties. Using these values in the final column of table 21.6 boosts the overall benefit values, even if there is a "senior discount" relative to one's peak value of statistical life. While a definitive set of estimates of the appropriate senior discount has not emerged, economic estimates of the role of such heterogeneity in benefit values are likely to reach a consensus in much the same way as agreement has been reached on the general range of the average value of statistical life.

But what should we do about equity concerns? If we value the lives of seniors less, isn't that unfair? Alternatively, isn't it unfair to value young people's lives at the same amount as seniors because doing so places a higher value on each year of life for seniors than each year of life for those at the early end of the age distribution? Viewed in this manner, the seniors' claim to be treated "fairly" may seem less compelling. However, if senior citizens do have a high willingness to pay for risk reductions, it would be inefficient and unfair not to count their benefit values.

Evaluating Performance

The objective of regulatory policy is not simply to promulgate and enforce regulations, but also to improve environmental outcomes. Assessing the impact of regulations is complicated by the fact that we observe trends in environmental quality, but we do not know what these trends would have been in the absence of regulation. Nevertheless, examination of pollution trends reveals the kinds of progress reflected in more formal statistical analyses.

Table 21.7 summarizes the pollution trends from 1970 to 2001 for five principal categories of air pollution emissions. One category not shown is that of lead pollution, which has been all but eliminated by EPA regulation. Since 1970 all but one pollutant category has exhibited

Table 21.7
National Pollution Emissions Trends

	Pollutant (millions of short tons)				
Year	PM-10	Sulfur Dioxides	Nitrogen Oxides	Carbon Monoxide	VOCs
1970	13.0	31.2	26.9	204.0	34.7
1975	7.6	28.0	26.4	188.4	30.8
1980	7.0	25.9	27.1	185.4	31.1
1981	6.5	24.6	26.8	182.2	29.3
1982	5.2	23.2	26.4	177.7	27.8
1983	6.0	22.6	26.2	179.2	28.5
1984	6.2	23.5	26.7	176.6	29.2
1985	41.3	23.3	25.8	176.8	27.4
1986	40.5	22.5	25.4	173.7	26.8
1987	40.8	22.3	25.6	173.0	26.7
1988	42.8	22.7	26.1	174.4	27.0
1989	40.8	22.8	25.4	160.5	25.6
1990	27.8	23.1	25.5	154.2	24.1
1991	27.3	22.4	25.2	147.1	23.6
1992	27.1	22.1	25.3	140.9	23.1
1993	27.4	21.8	25.4	135.9	22.7
1994	28.6	21.3	25.3	133.6	22.6
1995	25.8	18.6	25.0	126.8	22.0
1996	22.9	18.4	24.8	128.9	20.9
1997	22.9	18.8	24.7	117.9	19.5
1998	22.9	18.9	24.3	115.4	18.8
1999	21.6	17.7	23.7	117.2	19.4
2000	24.7	16.3	23.2	123.6	19.7
2001	24.1	15.8	22.3	120.8	18.0
Percentage Annual Growth Rate					
1970–1979	–5.6	–1.5	0.1	–0.9	–0.8
1980–1989	17.6	–1.3	–0.6	–1.4	–2.0
1990–1999	–2.5	–2.7	–0.8	–2.7	–2.2

Note: PM-10 refers to particulate matter less than 10 micrometers in diameter, and includes small particles of dust, dirt, soot, smoke, and liquid droplets often associated with fossil fuel combustion, fires, and natural windblown dust. VOCs are volatile organic compounds and are a precursor to ozone (ground-level smog). VOCs are emitted through fossil fuel combustion, as well as in chemical manufacturing, dry cleaning, and other activities using solvents.

Source: U.S. Environmental Protection Agency. Available at http://www.epa.gov/oar/oaqps/greenbk/o3co.html.

steady progress. Even particulate matter (PM-10, usually arising from fuel combustion, industrial processes, and motor vehicles) has exhibited improvement since 1988. The other pollution categories displayed more consistent improvement, including sulfur oxide emissions (chiefly arising from stationary fuel combustion and industrial processes), nitrogen oxide emissions (arising primarily from highway motor vehicles and cold-fired electric utility boilers), carbon monoxide emissions (primarily arising from highway motor vehicles), and volatile organic compounds (primarily from fossil fuel consumption and chemical manufacturing).

It is also noteworthy that the estimated benefits for this regulatory success exceeded the estimated costs. This regulation was one of the few EPA regulations that passed a test of economic desirability, and the result was a dramatic improvement in lead pollution levels achieved at reasonable cost.

Although a precise test of the EPA's impact on these various pollution measures has not yet been undertaken, it is clear that some progress has been made. Because one would have expected an increase in pollution levels with an expanding economy and a growing population, the fact that there was any decrease in the pollution, much less the dramatic declines that have occurred since 1970, is evidence of some payoff to society from the costs that have been incurred.

Summary

Environmental problems represent a classic situation in which there is an externality being imposed involuntarily. What is most noteworthy about this situation is that the optimal level of pollution is not zero. The fact that there is an externality that is being imposed without a voluntary contract does not mean that the activity should be prohibited. Whether we are talking about second-hand smoke or toxic waste disposal, the efficient level of pollution is generally not zero. However, the efficient level of pollution is also generally not going to be what arises within a market context, because the party generating the pollution has inadequate incentives to reflect the social cost imposed in its decisions.

Our review of the Coase theorem indicated that the main focal point should be the efficient pollution level, which is the level that would arise under a voluntary contractual situation if parties could contract costlessly. Examining pollution problems within the context of the bargaining problems used to illuminate the Coase theorem also sheds light on the distributional impacts involved. Assignment of property rights not only has distributional implication but also affects the long-run efficiency aspects of the system.

Similar concerns arise with respect to the choice of standards versus fines. Each of these approaches can provide for the same degree of short-run efficiency that can be achieved through a Coasian contractual outcome. However, standards differ from fines in terms of the total costs that will be borne by firms and in terms of their long-run efficiency. Moreover, there are a number of other features that distinguish the relative attractiveness of these options. Further exploration of the potential role of market trading options is long overdue, but in some contexts standards may be preferable, so that it will not always be the case that a particular class of policy options will be dominant.

The same kinds of methodologies that we apply to analyzing conventional pollutants, such as air pollution, can also be applied to analyzing global warming, as well as to more complex externalities, such as the group decisions that lead to overfishing. Examination of these various contexts as well as the policies that have been developed to address them suggest that considerable insight can be obtained by assessing how efficient markets would deal with externalities, if such markets existed.

Questions and Problems

1. Consider the following basic problem regarding a driver and a pedestrian in an accident situation. The driver makes a decision regarding his degree of care, but the pedestrian has no such decision to make. Payoffs to each party are as follows:

Driving Speed	Total Benefit to Driver	Expected Cost to Pedestrian
Rapidly	170	160
Moderately	100	40
Slowly	90	10

Suppose that instead of an anonymous driver-pedestrian relationship we had a two-person society, one driver and one pedestrian.

a. If the driver could undertake voluntary bargains that would be enforceable, what driving speed would result?

b. If both parties have equal bargaining power, what is the predicted settlement amount (that is, amount of transfer from pedestrian to driver)?

2. Suppose that a pulp-and-paper mill discharges water pollutants that impede the value of the stream for swimming. It would cost the mill $5,000 to install pollution abatement equipment to eliminate pollution, and doing so would result in an additional $10,000 in swimming benefits to the residents downstream.

a. If the residents are assigned the property rights, and if each party has equal bargaining power, what will be the predicted outcome and the dollar transfer between the two parties?

b. If the firm is assigned the property right to pollute, what will be the predicted outcome and the income transfer between the two parties?

3. The U.S. Department of Transportation has just rerouted the interstate highway through your yard, so that you now have to sell your house. The government proposes that we compensate you an amount equal to the market value of your home. Is this fair? Is it efficient? Answer the same questions supposing that, instead of the government wishing to purchase your house, I have decided that I want to live in your house. Would it be possible for me to evict you and to pay the market value? Would your answer change if we could accurately determine your reservation price for selling the house so that we would ensure that you would experience no utility loss from such an eviction? How do you believe the functioning of society would change if such a compensation mechanism were instituted?
4. The discussion in the chapter regarding the desirability of taxes and regulatory standards focused primarily on the short-run issues. However, these different policies also have important dynamic implications, particularly regarding the incentives for innovation. Under which type of governmental approach will there be greater incentives to innovate in a beneficial way from the standpoint of decreased environmental and health risks?
5. Suppose that the government must undertake an irreversible policy decision regarding the extent of air pollution regulation. The government is making this decision in a situation of uncertainty, however. In particular, there is some probability p that the benefits will remain the same as they are this year for all future years, but there is some probability $1 - p$ that benefits will be less in all future years. If we take into consideration the multiperiod aspects, should we err on the side of overregulation or underregulation, as compared with what we would do within a single-period choice?
6. Figure 21.11 illustrates a multiperson Prisoner's Dilemma for a situation in which the payoff curves for the two kinds of cars do not intersect. However, there may be externality situations in which the payoffs do intersect, inasmuch as the desirability of different activities may change in a differential manner for the two different decisions. If these payoff curves intersected, with the bottom payoff curve intersecting the top from below, what would be the nature of the market equilibrium that would prevail? Would this equilibrium be efficient?
7. Environmentalists argue that because the actions we take today will have an irreversible effect on climate change, we should take action now and err on the side of excessive restrictions. Some economists, however, have argued that because of the opportunity to acquire additional information, we should postpone a decision until we learn more about the merits of taking a regulatory action. Which strategy do you find more compelling and why?
8. Class Exercise: A useful class exercise is to develop a contingent valuation survey to determine society's willingness to pay to preserve some local environmental amenity. Examples include rare species of birds or plants in the area, or freedom from the noise of Jet-Skis at a local lake. What information would you provide respondents about the environmental amenity? What is the payment mechanism that you would establish for people's willingness to pay? Are there any tests that you can incorporate within the context of your survey to insure its validity, such as transitivity tests or tests for whether people are willing to pay more for broader environmental commodities that should have a larger value?