There are several problems with this mechanism, many of which are shared by other devices to solve the free rider problem. First, taxpayers may not be able to understand the system. (If you don't think this is a problem, try to explain it to a friend who has not had any economics courses.) Second, even if the scheme can be made comprehensible, taxpayers have to be willing to make the effort to compute their entire demand curves and report them to the government. People may feel it is not worth their time. Third, given that millions of people are involved in governmental decisions, the costs of gathering and assimilating all the information would be prohibitive.[14] (For relatively small groups like social clubs, this would not be as much of a problem.) We conclude that although preference revelation mechanisms of this kind provide interesting insights into the structure of the free rider problem, they are not a practical way for resolving it, at least for public sector decision making.

[14] There are some additional technical problems. The taxes collected may not balance the budget, and it may be possible for coalitions to form and thwart the system. See Tideman and Tullock [1976].

Chapter Five

Externalities

When man is happy, he is in harmony with himself and his environment.

—OSCAR WILDE

As a by-product of their activities, paper mills produce the chemical dioxin. It forms when the chlorine used for bleaching wood pulp combines with a substance in the pulp. Once dioxin is released into the environment, it ends up in everyone's fat tissue and in the milk of nursing mothers. According to some scientists, dioxin is responsible for birth defects and cancer, among other health problems.

Economists often claim that markets allocate resources efficiently (see Chapter 3). Dioxin is the outcome of the operation of markets. Does this mean that having dioxin in the environment is efficient? To answer this question, it helps to begin by distinguishing different ways in which people can affect each other's welfare.

Suppose large numbers of suburbanites decide they want to live in an urban setting. As they move to the city, the price of urban land increases. Urban property owners are better off, but the welfare of tenants already there decreases. Merchants in the city benefit from increased demand for their products, while their suburban counterparts are worse off. By the time the economy settles into a new equilibrium, the distribution of real income has changed substantially.

In this migration example, all the effects are transmitted *via changes in market prices*. Suppose that before the change in tastes, the allocation of resources was Pareto efficient. The shifts in supply and demand curves change relative prices, but competition guarantees that these will be brought into equality with the relevant marginal rates of substitution. Thus, the fact that the behavior of some people affects the welfare of others does *not* necessarily cause market failure. As long as the effects are transmitted via prices, markets are efficient.[1]

The dioxin case embodies a different type of interaction from the urban land example. The decrease in welfare of the dioxin victims is not a result of price changes. Rather, the output choices of the paper mill factories directly affect the utilities of the neighboring people. When the activity of one entity (a person or a firm) directly affects the welfare of another in a way that is outside the market mechanism, that effect is called an **externality** (because one entity directly affects the welfare of another entity that is "external" to the market). Unlike effects that are transmitted through market prices, externalities adversely affect economic efficiency.

externality

An activity of one entity that affects the welfare of another entity in a way that is outside the market mechanism.

[1] Of course, the new pattern of prices may be more or less desirable from a distributional point of view, depending on one's ethical judgments as embodied in the social welfare function. Effects on welfare that are transmitted via prices are sometimes referred to as pecuniary externalities. Mishan [1971] argues convincingly that because such effects are part of the normal functioning of the market, this is a confusing appellation. It is mentioned here only for the sake of completeness and is ignored henceforth.

In this chapter, we analyze these inefficiencies and possible remedies for them. One of the most important applications of externality theory arises in the debate over environmental quality, and much of the discussion focuses on this issue.

▸ THE NATURE OF EXTERNALITIES

Suppose Bart operates a factory that dumps its garbage into a river nobody owns. Lisa makes her living by fishing from the river. Bart's activities make Lisa worse off in a direct way that is not the result of price changes, so the harm done to Lisa is not incorporated into Bart's market decision. In this example, clean water is an input to Bart's production process. It gets used up just like all other inputs: land, labor, capital, and materials. Clean water is also a scarce resource with alternative uses, such as fishing by Lisa and swimming. As such, efficiency requires that for the water he uses, Bart should pay a price that reflects water's value as a scarce resource that can be used for other activities. Instead, Bart pays a zero price and, as a consequence, uses the water in inefficiently large quantities.

Posing the externality problem this way allows us to expose its source. Bart uses his other inputs efficiently because he must pay their owners prices that reflect their value in alternative uses. Otherwise, the owners of the inputs simply sell them elsewhere. However, if no one owns the river, there is no market for its use and everyone can use it for free. An externality, then, is a consequence of the failure or inability to establish property rights. If someone owned the river, people would have to pay for its use, and no externality would materialize.

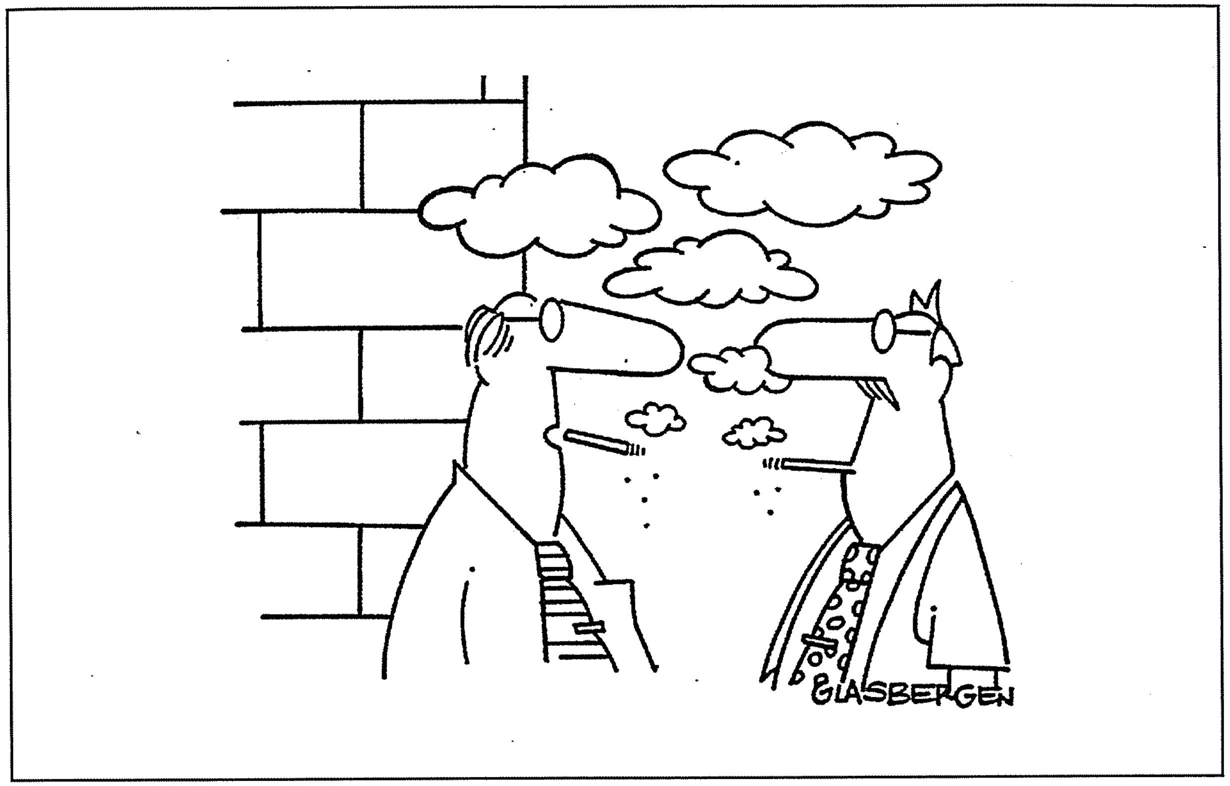
Suppose Lisa owned the stream. She could charge Bart a fee for polluting that reflected the damage done to her catch. Bart would take these charges into account when making his production decisions and no longer use the water inefficiently. On the other hand, if Bart owned the stream, he could make money by charging Lisa for the privilege of fishing in it. The amount of money that Lisa would be willing to pay Bart for the right to fish in the stream would depend on the amount of pollution present. Hence, Bart would have an incentive not to pollute excessively. Otherwise, he could not make as much money from Lisa.

As long as someone owns a resource, its price reflects the value for alternative uses, and the resource is therefore used efficiently (at least in the absence of any other "market failures"). In contrast, resources that are owned in common are abused because no one has an incentive to economize in their use.

To expand on the subject, note the following characteristics of externalities:

Externalities Can Be Produced by Consumers as Well as Firms Not all externalities are produced by firms. Just think of the person who smokes a cigar in a crowded room, lowering others' utility by using up the common resource, fresh air.

Externalities Are Reciprocal in Nature In our example, it seems natural to refer to Bart as the "polluter." However, we could just as well think of Lisa as "polluting" the river with fishermen, increasing the social cost of Bart's production. As an alternative to fishing, using the river for waste disposal is not obviously worse from a social point of view. As we show later, it depends on the costs of alternatives for each of these two activities.

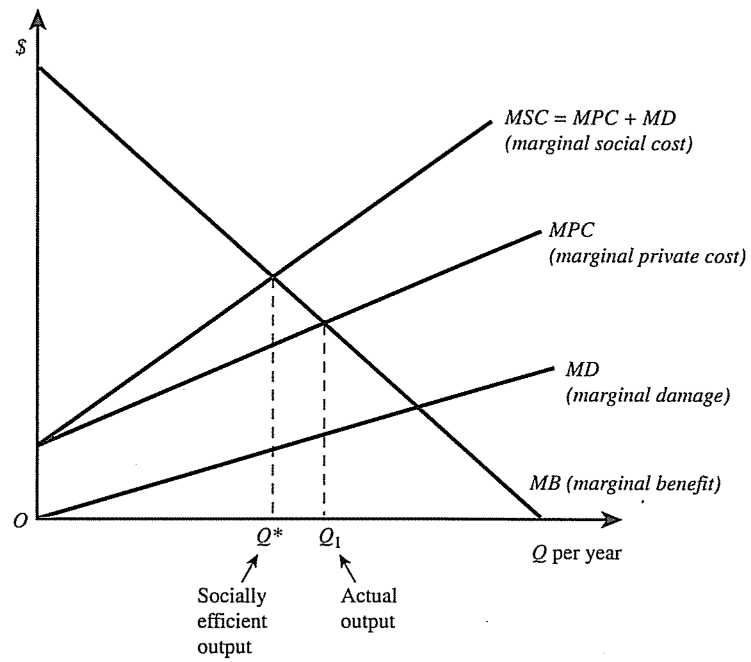


"We make clouds, clouds make rain, and rain spoils ball games. That's why people don't like smokers!" © 2000 Randy Glasbergen. www.glasbergen.com.

Externalities Can Be Positive Suppose that in response to a terrorist threat you were to get yourself vaccinated against smallpox. You would incur some costs: the price of the vaccination, the associated discomfort, and the slight risk that it would induce a case of the disease. There would be a benefit to you in terms of a reduced probability of being stricken by the disease in the event of a bioterrorism attack. However, you simultaneously would benefit other members of your community, who would be less likely to come down with the disease because they could not catch it from you. But neither you nor other people take into account such external benefits when weighing the benefits and costs of getting vaccinated, and hence not enough people are vaccinated in the absence of some public intervention.

Public Goods Can Be Viewed as a Special Kind of Externality Specifically, when an individual creates a positive externality with full effects felt by every person in the economy, the externality is a pure public good. At times, the boundary between public goods and externalities is a bit fuzzy. Suppose that I install in my backyard a device for electrocuting mosquitoes. If I kill the whole community's mosquitoes, then I have, in effect, created a pure public good. If only a few neighbors are affected, then it is an externality. Although positive externalities and public goods are quite similar from a formal point of view, in practice it is useful to distinguish between them.

Figure 5.1
An externality problem
The marginal social cost of production is the marginal private cost to Bart plus the marginal damage done to Lisa. Bart produces where his marginal private cost equals marginal benefit, output Q_1. However, the efficient output is Q^*, where marginal social cost equals marginal benefit.



GRAPHICAL ANALYSIS

Figure 5.1 analyzes the Bart-Lisa example described earlier. The horizontal axis measures the amount of output, Q, produced by Bart's factory, and the vertical axis measures dollars. The curve labeled *MB* indicates the marginal benefit to Bart of each level of output; it is assumed to decline as output increases.[2] Also associated with each level of output is some marginal private cost, *MPC*. Marginal private cost reflects payments made by Bart for productive inputs and is assumed here to increase with output. As a by-product of its activities, the factory produces pollution that makes Lisa worse off. Assume that there is a fixed amount of pollution per unit of output, so as the factory's output increases, so does the amount of pollution it creates. The marginal damage inflicted on Lisa by the pollution at each level of output is denoted by *MD*. *MD* is drawn sloping upward, reflecting the assumption that as Lisa is subjected to additional pollution, she becomes worse off at an increasing rate.

If Bart wants to maximize profits, how much output does he produce? Bart produces each unit of output for which the marginal benefit *to him* exceeds the marginal cost *to him*. In Figure 5.1, he produces all levels of output for which *MB* exceeds *MPC* but does not produce where *MPC* exceeds *MB*. Thus, he produces up to output level Q_1, at which *MPC* intersects *MB*.

[2] If Bart consumes all the output of his factory, then the declining *MB* reflects the diminishing marginal utility of output. If Bart sells his output in a competitive market, *MB* is constant at the market price.

From society's point of view, production should occur as long as the marginal benefit *to society* exceeds the marginal cost *to society*. The marginal cost to society has two components: First are the inputs purchased by Bart. Their value is reflected in *MPC*. Second is the marginal damage done to Lisa as reflected in *MD*. Hence, marginal social cost is *MPC plus MD*. Graphically, the marginal social cost schedule is found by adding together the heights of *MPC* and *MD* at each level of output. It is depicted in Figure 5.1 as *MSC*. Note that, by construction, the vertical distance between *MSC* and *MPC* is *MD*. (Because $MSC = MPC + MD$, it follows that $MSC - MPC = MD$.)

Efficiency from a social point of view requires production of only those units of output for which *MB* exceeds *MSC*. Thus, output should be at Q^*, where the two schedules intersect.

Implications

This analysis suggests the following observations: First, unlike the case without externalities, private markets need not produce the socially efficient output level. In particular, when a good generates a negative externality, too much of it is produced relative to the efficient output.[3]

Second, the model not only shows that efficiency would be enhanced by a move from Q_1 to Q^* but also provides a way to measure the benefits from doing so. Figure 5.2 replicates from Figure 5.1 the marginal benefit (*MB*), marginal private cost (*MPC*), marginal damage (*MD*), and marginal social cost (*MSC*) schedules. When output is cut from Q_1 to Q^*, Bart loses profits. To calculate the precise size of his loss, recall that the marginal profit to Bart associated with each unit of output is the difference between marginal benefit and marginal private cost. If the marginal private cost of the eighth unit is \$10 and its marginal benefit is \$12, the marginal profit is \$2. Geometrically, the marginal profit on a given unit of output is the vertical distance between *MB* and *MPC*. If Bart is forced to cut back from Q_1 to Q^*, he therefore loses the difference between the *MB* and *MPC* curves for each unit of production between Q_1 and Q^*. This is area *dcg* in Figure 5.2.

At the same time, however, Lisa becomes better off because as Bart's output falls, so do the damages to her fishery. For each unit decline in Bart's output, Lisa gains an amount equal to the marginal damage associated with that unit of output. In Figure 5.2, Lisa's gain for each unit of output reduction is the vertical distance between *MD* and the horizontal axis. Therefore, Lisa's gain when output is reduced from Q_1 to Q^* is the area under the marginal damage curve between Q^* and Q_1, *abfe*. Now note that *abfe* equals area *cdhg*. This is by construction—the vertical distance between *MSC* and *MPC* is *MD*, which is the same as the vertical distance between *MD* and the horizontal axis.

In sum, if output were reduced from Q_1 to Q^*, Bart would lose area *dcg* and Lisa would gain area *cdhg*. Provided that society views a dollar to Bart as equivalent to a dollar to Lisa, then moving from Q_1 to Q^* yields a net gain to society equal to the difference between *cdhg* and *dcg*, which is *dhg*.

[3] This model assumes the only way to reduce pollution is to reduce output. If antipollution technology is available, it may be possible to maintain output and still reduce pollution. Later in the chapter we examine such approaches to pollution reduction. However, for now it is enough to point out that the analysis is basically the same, because the adoption of new technologies requires the use of resources.

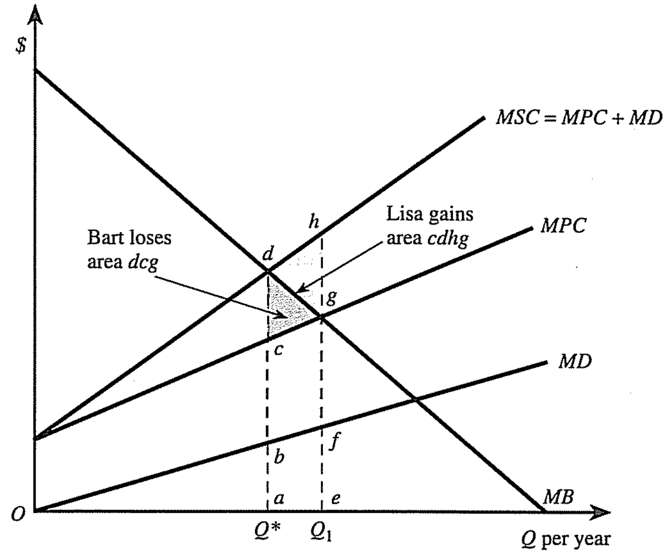


Figure 5.2

Gains and losses from moving to an efficient level of output

When output falls from Q_1 to Q^*, Bart loses area *dcg* in profits. However, the reduction in Bart's output increases Lisa's welfare by area *cdhg*. Thus, the net gain to society is area *dhg*.

Third, the analysis implies that, in general, zero pollution is not socially desirable. Finding the right amount of pollution requires trading off its benefits and costs, and the optimum generally occurs at some positive level of pollution. Because virtually all productive activity involves some pollution, requiring pollution to be set at zero is equivalent to banning all production, clearly an inefficient solution. If all this seems only like common sense, it is. But note that Congress once set as a national goal that "the discharge of pollutants into the navigable waters be eliminated by 1985." The adoption of such infeasible and inefficient objectives is not only silly but, as shall be argued later, may also actually hinder *any* movement away from points like Q_1.

Finally, implementing the framework of Figure 5.2 requires more than drawing hypothetical marginal damage and benefit curves. Their actual locations and shapes must be determined, at least approximately. However, difficult practical questions arise when it comes to identifying and valuing pollution damage.

Which Pollutants Do Harm? In our earlier example, it was entirely clear that Bart's factory caused harm to Lisa by reducing the number of fish she could catch. However, in the real world, it is typically difficult to determine which pollutants cause harm and how much. We now discuss some empirical approaches to this problem.

EMPIRICAL EVIDENCE

What Is the Effect of Pollution on Health?

Total suspended particles (TSPs) are widely considered to be the air pollutant most damaging to health. Several studies have established a correlation between TSPs and mortality rates. However, it is difficult to discern whether the link is causal. The difficulty arises because scientists cannot perform randomized studies on the effects of pollution. Instead, investigators must rely on cross-sectional or time-series observational evidence. These studies could yield biased results if other factors that differ across location or time affect both air pollution and mortality. For example, industrialized areas might have more air pollution and also have higher mortality rates independent of air quality because they attract lower-income, less healthy residents. Therefore, the correlation between air pollution and mortality might not be causal.

A further complication is that these studies are unable to measure the *lifetime* exposure of adults to air pollution. Since people move in and out of cities, it is difficult to measure lifetime exposure to pollution and its link to health outcomes.

Chay and Greenstone [2003] study the impact of air pollution on mortality. They focus on infants, because unlike adults, it is possible to know an infant's lifetime exposure to pollution. They also conduct a quasi-experimental analysis to address the potential biases that can arise with observational analyses. They take advantage of the fact that the recession of the early 1980s led to sharp reductions in TSPs in some areas of the United States but not others. Importantly, the changes in air pollution appear to have been virtually random—the areas that experienced substantial TSP reductions had similar overall characteristics to those that did not. By comparing the two types of areas, Chay and Greenstone [2003] found that a 1 percent reduction in TSPs led to a 0.35 percent reduction in the infant mortality rate. This implies that because of the TSPs reductions, 2,500 fewer infants died from 1980–1982 than otherwise would have been the case.

Even once a pollutant as been identified as causing harm, policymakers must consider the risks associated with reducing levels of the pollutant. For example, in order to make gasoline burn more cleanly and thus reduce air pollution, policymakers required oil companies to add a chemical ingredient called M.T.B.E. to gasoline. However, in 1999 the Environmental Protection Agency stopped this requirement because scientists discovered that, when it leaked, M.T.B.E. was a potentially dangerous source of *water* pollution. In this context, it is disconcerting to note that there is some evidence that certain chemicals that are unregulated by the US government pose a greater cancer risk than those that are regulated (see Viscusi [1995]).

What Activities Produce Pollutants? Once a harmful pollutant is identified, policymakers must identify which production processes generate it. Consider acid rain, a phenomenon of widespread concern. Scientists have shown that acid rain forms when sulfur oxides and nitrogen oxides emitted into the air react with water vapor to create acids. These acids fall to earth in rain and snow, increasing the general level of acidity with potentially harmful effects on plant and animal life.

However, it is not known just how much acid rain is associated with factory production and how much with natural activities such as plant decay and volcanic eruptions. Moreover, determining what amounts of nitrogen and sulfur emissions generated in a given region eventually become acid rain is difficult. It depends in part on local weather conditions and on the extent to which other pollutants such as nonmethane hydrocarbons are present. This highlights the difficulty of assessing which production activities cause acid rain and should thus be subject to government intervention.

What Is the Value of the Damage Done? The marginal damage schedule shows the dollar value of the external costs imposed by each additional unit of output. Therefore, once the physical damage a pollutant creates is determined, the dollar value of that damage must be calculated. When economists think about measuring the value of something, typically they think of people's willingness to pay for it. If you are willing to pay $210 for a bicycle, that is its value to you.

Unlike bicycles, pollution reduction is generally not bought and sold in explicit markets. (Some exceptions are discussed shortly.) How, then, can people's marginal willingness to pay for pollution removal be measured? Some attempts have been made to infer it indirectly by studying housing prices. When people shop for houses, they consider both the quality of the house itself and the characteristics of the neighborhood, such as cleanliness of the streets and quality of schools. Suppose that families also care about the level of air pollution in the neighborhoods. Consider two identical houses situated in two identical neighborhoods, except that the first is in an unpolluted area and the second is in a polluted area. We expect the house in the unpolluted area to have a higher price. This price differential approximates people's willingness to pay for clean air.

These observations suggest a natural strategy for estimating people's willingness to pay for clean air. Using multiple regression analysis (see Chapter 2), researchers can estimate the relationship between housing prices and air quality using a sample of houses in a given area or areas. Many economics studies have followed this strategy, and we now highlight one of them.

EMPIRICAL EVIDENCE

The Effect of Air Pollution on Housing Values

Using regression analysis, a researcher can estimate the correlation between air quality and housing prices, holding all other measured characteristics constant. However, it is difficult to establish whether this is a causal relationship because other unmeasured characteristics could affect both air quality and housing prices. For example, highly industrialized neighborhoods might have lower housing prices because they are visually less attractive and also have lower air quality, but this does not mean that air quality causes the lower prices.

Chay and Greenstone [2005] analyze a quasi-experiment to estimate the causal relationship between TSPs and the mean housing values in a county. For their analysis, they rely on legislation in the 1970s that set a limit on TSP emissions. Counties that were above this limit were subject to strict regulation, while those below the limit (no matter how close) were not subject to the same strict regulations. In effect, then, the counties above the limit were the treatment group and those below the limit were the control group. Chay and Greenstone [2005] found that the counties in the treatment group experienced a large drop in TSPs due to the regulations, which led to an increase in housing prices. According to their estimates, the improvements in air quality stemming from the regulation led to a $45 billion aggregate increase in housing values between 1970 and 1980.

Aside from the difficulty of measuring the effect of air quality on housing prices, a more fundamental concern is with the validity of a willingness-to-pay measure for cleaner air. People may be ignorant about the effects of air pollution on their health, and hence underestimate the value of reducing it. Also, the willingness-to-pay measure ignores equity concerns. In sum, the econometric approach to valuation is promising, but it does not definitively determine the value of damage done.

Conclusion

Implementing the framework of Figure 5.2 requires the skills of biologists, engineers, ecologists, and health practitioners, among others, in order to estimate the marginal damages associated with pollution. Investigating a pollution problem requires a resolutely interdisciplinary approach. Having said this, however, we emphasize that even with superb engineering and biological data, one simply cannot make efficient decisions without applying the economist's tool of marginal analysis.

▶ PRIVATE RESPONSES

In the presence of externalities, an inefficient allocation of resources emerges if nothing is done about it. This section discusses the circumstances under which private individuals, acting on their own, can avoid externality problems.

Bargaining and the Coase Theorem

Recall our earlier argument that the root cause of the inefficiencies associated with externalities is the absence of property rights. When property rights are assigned, individuals may respond to the externality by bargaining with each other. To see how, suppose property rights to the river are assigned to Bart. Assume further that it is costless for Lisa and Bart to bargain with each other. Is it possible for the two parties to strike a bargain that results in output being reduced from Q_1?

Bart would be willing to not produce a given unit of output as long as he received a payment that exceeded his net incremental gain from producing that unit ($MB - MPC$). On the other hand, Lisa would be willing to pay Bart not to produce a given unit as long as the payment was less than the marginal damage done to her, MD. As long as the amount that Lisa is willing to pay Bart exceeds the cost to Bart of not producing, the opportunity for a bargain exists. Algebraically, the requirement is that $MD > (MB - MPC)$. Figure 5.3 (which reproduces the information from Figure 5.1) indicates that at output Q_1, $MB - MPC$ is zero, while MD is positive. Hence, MD exceeds $MB - MPC$, and there is scope for a bargain.

Similar reasoning indicates that the payment Lisa would be willing to make exceeds $MB - MPC$ at every output level to the right of Q^*. In contrast, to the left of Q^*, the amount of money Bart would demand to reduce his output would exceed what Lisa would be willing to pay. Hence, Lisa pays Bart to reduce output just to Q^*, the efficient level. We cannot tell without more information exactly how much Lisa ends up paying Bart, although the total payment will be at least *dcg* (the amount Bart loses by decreasing output to Q^*) and no greater than *cdhg* (the amount that Lisa gains by having Bart decrease output to Q^*). The exact amount depends on the relative bargaining strengths of the two parties. Regardless of how the gains from the bargain are divided, however, production ends up at Q^*.

Now suppose the shoe is on the other foot, and Lisa is assigned the property rights to the stream. Bart cannot produce any output without first gaining Lisa's permission. The bargaining process now consists of Bart paying for Lisa's consent to pollute. Lisa is willing to accept some pollution as long as the payment she receives

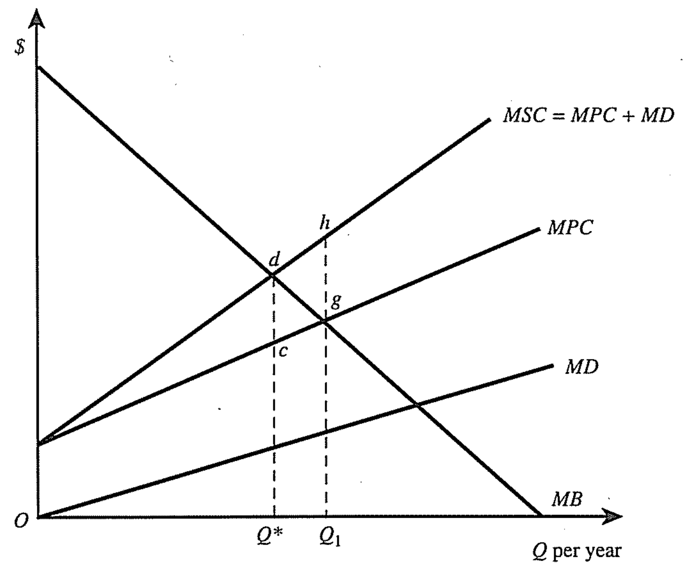


Figure 5.3
Coase Theorem
If Bart has property rights to the river, he will reduce output by one unit as long as he receives a payment that exceeds the incremental profit he would have received from producing that unit ($MB - MPC$). Lisa is willing to pay Bart to reduce a unit of production as long as the payment is less than the damage the output causes her, MD. There is room for them to bargain at any level of output greater than Q^*.

from Bart for each unit of his output is greater than the marginal damage (MD) caused by that output to her fishing enterprise. Bart finds it worthwhile to pay for the privilege of producing as long as the amount is less than the value of $MB - MPC$ for that unit of output. Notice that for the first unit of output Bart produces, his marginal profit ($MB - MPC$) far exceeds the marginal damage (MD) to Lisa, so there is ample room to bargain and allow Bart to produce this unit. Applying this reasoning to each additional unit of production shows that they have every incentive to reach an agreement whereby Lisa sells Bart the right to produce at Q^*.

Two important assumptions played a key role in the preceding analysis:

1. The costs to the parties of bargaining are low.
2. The owners of resources can identify the source of damages to their property and legally prevent damages.

A way to summarize the implications of the discussion surrounding Figure 5.3 is that, under these assumptions, the efficient solution will be achieved *independently* of who is assigned the property rights, as long as *someone* is assigned those rights. This result, known as the **Coase Theorem** (after Nobel laureate Ronald Coase), implies that once property rights are established, no government intervention is required to deal with externalities [Coase, 1960].

Coase Theorem
Provided that transaction costs are negligible, an efficient solution to an externality problem is achieved as long as someone is assigned property rights, independent of who is assigned those rights.

However, externalities such as air pollution involve millions of people (both polluters and pollutees). It is difficult to imagine them getting together for negotiations at a sufficiently low cost.[4] Further, even if property rights to air were established, it is not clear how owners would be able to identify which of thousands of potential polluters was responsible for dirtying their airspace and for what proportion of the damage each was liable.

[4] Although transaction costs might make an efficient outcome unlikely through bargaining, the transaction costs of implementing a government solution might not be less.

The Coase Theorem is most relevant for cases in which only a few parties are involved and the sources of the externality are well defined. Even when these conditions hold, the assignment of property rights *is* relevant from the point of view of income distribution. Property rights are valuable; if Lisa owns the stream, it will increase her income relative to Bart's, and vice versa.

Assigning property rights along Coasian lines could help solve some significant environmental problems. One commentator, for example, urged that property rights be assigned to rivers in the United States, pointing out that "in England and Scotland, private ownership of the rivers and waterways has successfully prevented overfishing and controlled water pollution for 800 years. The owners simply charge others for the right to fish in their section of the river. Consequently, the owners have an economic incentive to maintain the fish population and keep the waterway clean" [Conda, 1995, p. A18].

Mergers

One way to deal with an externality is to "internalize" it by combining the involved parties. For simplicity, imagine there is only one polluter and one pollutee, as in the Bart-Lisa scenario from earlier in the chapter. As stressed already, if Bart took into account the damages he imposed on Lisa's fishery, then a net gain would be possible. (Refer back to the discussion surrounding Figure 5.2.) In other words, if Bart and Lisa coordinated their activities, then the profit of the joint enterprise would be higher than the sum of their individual profits when they don't coordinate. In effect, by failing to act together, Bart and Lisa are just throwing away money!

The market, then, provides a strong incentive for the two firms to merge—Lisa can buy the factory, Bart can buy the fishery, or some third party can buy them both. Once the two firms merge, the externality is internalized—it is taken into account by the party that generates the externality. For instance, if Bart purchased the fishery, he would willingly produce less output than before, because at the margin doing so would increase the profits of his fishery subsidiary more than it decreased the profits from his factory subsidiary. Consequently, the external effects would not exist, and the market would not be inefficient. Put another way, an outside observer would not even characterize the situation as an "externality" because all decisions would be made within a single firm.

Social Conventions

Unlike firms, individuals cannot merge to internalize externalities. However, certain social conventions can be viewed as attempts to force people to take into account the externalities they generate. Schoolchildren are taught that littering is irresponsible and not "nice." If this teaching is effective, a child learns that even though she bears a small cost by holding on to a candy wrapper or a banana peel until she finds a garbage can, she should incur this cost because it is less than the cost imposed on other people by having to view her unsightly garbage. Think about the golden rule, "Do unto others as you would have others do unto you." A (much) less elegant way of expressing this sentiment is, "Before you undertake some activity, take into account its external marginal benefits and costs." Some moral precepts, then, induce people to empathize with others, and hence internalize the externalities their behavior may create. In effect, these precepts correct for the absence of missing markets.

PUBLIC RESPONSES TO EXTERNALITIES: TAXES AND SUBSIDIES

In cases where individuals acting on their own cannot attain an efficient solution, government can intervene by levying taxes and subsidies on certain market activities.[5]

Taxes

Pigouvian tax

A tax levied on each unit of an externality-generator's output in an amount equal to the marginal damage at the efficient level of output.

Bart produces inefficiently because the prices he faces for inputs incorrectly signal social costs. Specifically, because his input prices are too low, the price of his output is too low. A natural solution, suggested by the British economist A. C. Pigou in the 1930s, is to levy a tax on the polluter that makes up for the fact that some of his inputs are priced too low. A **Pigouvian tax** is a tax levied on each unit of a polluter's output in an amount just equal to the marginal damage it inflicts *at the efficient level of output.* Figure 5.4 reproduces the example of Figure 5.1. In this case, the marginal damage at the efficient output Q^* is distance *cd*. This is the Pigouvian tax. (Remember that the vertical distance between *MSC* and *MPC* is *MD*.)

How does Bart react if a tax of *cd* dollars per unit of output is imposed? The tax raises Bart's effective marginal cost. For each unit he produces, Bart has to make payments both to the suppliers of his inputs (measured by *MPC*) *and* to the tax collector (measured by *cd*). Geometrically, Bart's new marginal cost schedule is found by adding *cd* to *MPC* at each level of output. This involves shifting up *MPC* by the vertical distance *cd*.

Profit maximization requires that Bart produce where marginal benefit equals his marginal cost. This now occurs at the intersection of *MB* and $MPC + cd$, which is at the efficient output Q^*. In effect, the tax forces Bart to take into account the costs of the externality that he generates and induces him to produce efficiently. Note that the tax generates revenue of *cd* dollars for each of the *id* units produced ($id = OQ^*$). Hence, tax revenue is $cd \times id$, which is equal to the area of rectangle *ijcd* in Figure 5.4. It would be tempting to use these revenues to compensate Lisa, who still is being hurt by Bart's activities, although to a lesser extent than before the tax. However, caution must be exercised. If it becomes known that anyone who fishes along the river receives a payment, then some people may choose to fish there who otherwise would not have done so. Recall the reciprocal nature of externalities. Compensation would lead those who fish to ignore the costs they impose on Bart's production. The result is an inefficiently large amount of fishing done in the river. The key point is that compensation to the victim of the pollution is not necessary to achieve efficiency, and indeed will likely lead to inefficiency.

Practical problems arise in implementing a Pigouvian tax system. In light of the previously mentioned difficulties in estimating the marginal damage function, finding the correct tax rate is bound to be hard. Still, sensible compromises can be made. Consider the externality of harmful emissions from automobiles. In theory, a tax

[5] In this and the next section we explore a number of ways in which the government can intervene to address externalities. However, the list of possibilities considered is by no means exhaustive. See Stavins [2003] for a careful discussion of several alternatives.

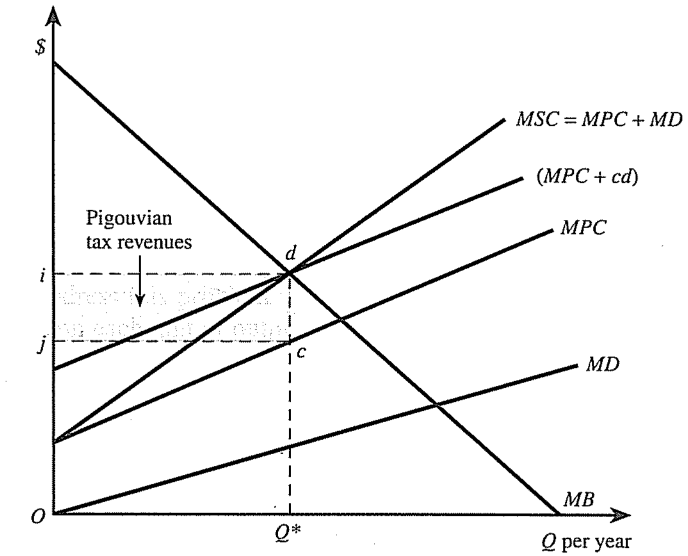


Figure 5.4

Analysis of a Pigouvian tax

The Pigouvian tax shifts up Bart's private marginal cost curve by an amount equal to the marginal external damage at the efficient output, *cd*. Bart now maximizes profit at the efficient output Q^*.

based on the number of miles driven enhances efficiency. Even more efficient would be a tax on the number of miles driven that also varies by location and time of day, since the pollution is more harmful when emitted in populated areas and when emitted during times of high traffic congestion. But a per-mile tax that varies by time and place could be prohibitively expensive to administer. The government might instead levy a gasoline tax, even though it is not gasoline use per se that determines the size of the externality. The gasoline tax would not lead to the most efficient outcome, but it still might be a substantial improvement over the status quo.

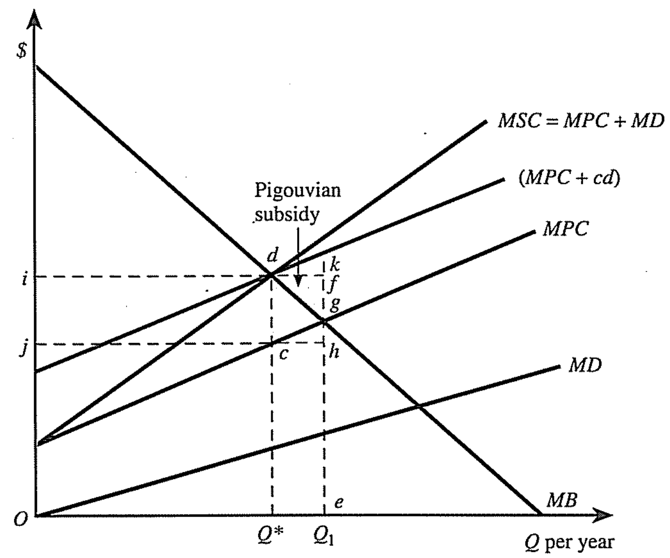
Subsidies

Assuming a fixed number of polluting firms, the efficient level of production can be obtained by paying the polluter not to pollute. Although this notion may at first seem peculiar, it works much like the tax scheme. This is because a subsidy for not polluting is simply another method of raising the polluter's effective production cost.

Suppose the government announces that it will pay Bart a subsidy of *cd* for each unit of output below Q_1 he does *not* produce. What will Bart do? In Figure 5.5, Bart's marginal benefit at output level Q_1 is the distance between *MB* and the horizontal axis, *ge*. The marginal cost of producing at Q_1 is the sum of the amount Bart pays for his inputs (which we read off the *MPC* curve) *and* the subsidy of *cd* that he forgoes by producing. Once again, then, the perceived marginal cost schedule is $MPC + cd$. At output Q_1, this is distance *ek* ($= eg + gk$).

But *ek* exceeds the marginal benefit, *ge*. As long as the marginal cost exceeds the marginal benefit at Q_1, it does not make sense for Bart to produce this last unit of output. Instead, he should forgo its production and accept the subsidy. The same line of reasoning indicates that Bart chooses not to produce any output in excess of Q^*. At all output levels to the right of Q^*, the sum of the marginal private cost and the subsidy exceeds the marginal benefit. On the other hand, at all points to the left of Q^*,

Figure 5.5
Analysis of a Pigouvian subsidy
A Pigouvian subsidy for each unit Bart does *not* produce shifts up his private marginal cost curve by the amount of the per-unit subsidy, *cd*, and induces him to produce at the efficient level of output.



it is worthwhile for Bart to produce even though he has to give up the subsidy. For these output levels, the total opportunity cost, $MPC + cd$, is less than the marginal benefit. Hence, the subsidy induces Bart to produce just to Q^*, the efficient output.

The distributional consequences of the tax and subsidy schemes differ dramatically. Instead of having to pay the tax of *ijcd*, Bart receives a payment equal to the number of units of forgone production, *ch*, times the subsidy per unit, *cd*, which equals rectangle *dfhc* in Figure 5.5.[6] That an efficient solution can be associated with different income distributions is no surprise. It is analogous to the result from Chapter 3—there are an infinite number of efficient allocations in the Edgeworth Box, each of which is associated with its own distribution of real income.

In addition to the problems associated with the Pigouvian tax scheme, the subsidy program has a few of its own. First, recall that the analysis of Figure 5.5 assumes a fixed number of firms. The subsidy leads to higher profits, so in the long run, more firms may be induced to locate along the river. The subsidy may cause so many new firms to relocate on the river that total pollution actually increases.

Second, subsidies may be ethically undesirable. As Mishan [1971, p. 25] notes:

> It may be argued [that] the freedom to operate noisy vehicles, or pollutive plant, does incidentally damage the welfare of others, while the freedom desired by members of the public to live in clean and quiet surroundings does not, of itself, reduce the welfare of others. If such arguments can be sustained, there is a case . . . for making polluters legally liable.

[6] In Figure 5.5, Q_1 is the baseline from which Bart's reduction in output is measured. In principle, any baseline to the right of Q^* would do. One potential problem with subsidies is that firms might engage in inefficient actions that increase their assigned baselines. For example, if a firm believes that a future baseline will be dependent on current output, it might produce more than the efficient amount in order to overstate its baseline.

PUBLIC RESPONSES TO EXTERNALITIES: EMISSIONS FEES AND CAP-AND-TRADE PROGRAMS

The previous section demonstrated how a tax on each unit of Bart's output can lead to the socially efficient outcome. One problem with this approach is that it might not give Bart the proper incentives to search for ways to reduce pollution other than reducing output. Why should Bart install pollution control technology that reduces his emissions per unit of output if doing so won't change his tax bill?

One way to address this problem is to levy a Pigouvian tax on each unit of emissions rather than on each unit of output. This tax is called an **emissions fee.** To examine such a tax, consider Figure 5.6, which shows Bart's annual level of pollution reduction on the horizontal axis. In this diagram the curve labeled *MSB* shows the marginal social benefit to Lisa of each unit of pollution Bart reduces. In other words, *MSB* shows the fall in Lisa's costs for each unit reduction in Bart's pollution. This curve is drawn downward sloping, reflecting our assumption that Lisa becomes worse off at an increasing rate for each additional unit of pollution. The curve labeled *MC* shows the marginal cost to Bart of reducing each unit of pollution. Bart's costs for reducing pollution can stem from reducing output, shifting to cleaner inputs, or installing a new technology to control pollution. We assume this curve is upward sloping, suggesting that the cost to Bart of reducing pollution increases at an increasing rate.

emissions fee
A tax levied on each unit of pollution.

If Coasian bargaining does not occur and the government does not intervene, then Bart has no incentive to reduce pollution and will be at point *O*. However, the efficient outcome is where the marginal cost to Bart of cutting pollution equals the marginal benefit to Lisa of the pollution reduction, which occurs at point e^*. At any point to the left of e^*, the benefit of further pollution reduction outweighs the cost,

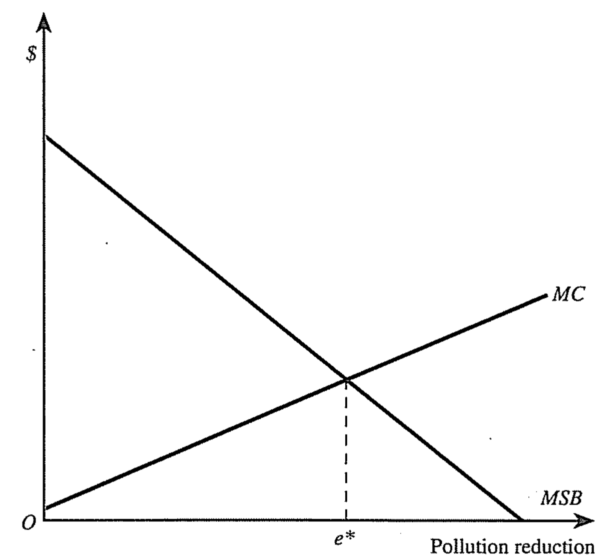


Figure 5.6
The market for pollution reduction
Efficiency requires that Bart reduce pollution if the marginal social benefit (*MSB*) is greater than the marginal cost (*MC*) of doing so. Thus, e^* is the efficient amount of pollution reduction.

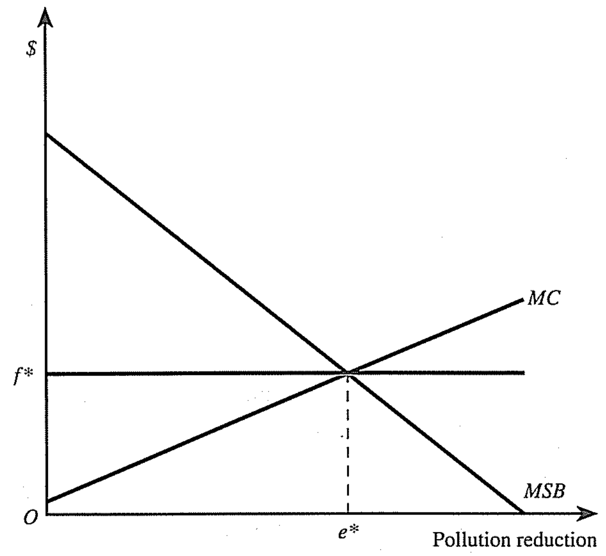


Figure 5.7
Using an emissions fee to achieve efficient pollution reduction
Bart reduces pollution by an additional unit as long as the cost of doing so (MC) is below the amount of the emissions fee. Therefore, an emissions fee set at f^* leads to the efficient amount of pollution reduction, e^*

so more reduction improves efficiency. At any point to the right of e^*, the benefit of the last unit of pollution reduced is not worth the cost of doing so, so less reduction improves efficiency.

What can the government do to attain e^*, the efficient amount of pollution reduction? We will examine three different approaches: emissions fee, cap-and-trade, and command-and-control regulation.

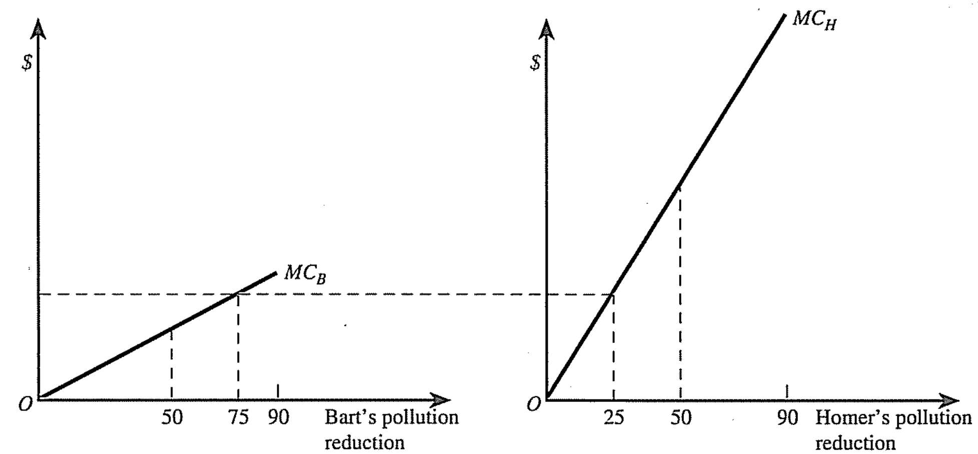
Emissions Fee

An emissions fee works much the same way as the tax we considered earlier. The only difference is that in this case a tax is levied on each unit of pollution rather than on each unit of output. Figure 5.7 replicates the curves from Figure 5.6. Recall that with no government intervention, Bart does not reduce emissions, so he is at point O. Now assume that the government levies an emissions fee that charges f^* for each unit of pollution, where f^* is the marginal social benefit of pollution reduction at the efficient level e^*. How does Bart respond?

Bart incurs a cost of MC for each unit he reduces emissions. However, with the emissions fee in place, his tax bill goes down by f^* for each unit of pollution he cuts. If the amount he saves in taxes per unit exceeds the cost of reducing pollution by another unit, Bart pollutes less. Algebraically, if $f^* > MC$, he reduces pollution. Figure 5.7 indicates that this condition holds at all points to the left of e^*, so Bart will cut back on polluting until the efficient point. He won't reduce pollution further because the marginal cost of doing so exceeds the reduction he achieves in his taxes.

This example demonstrates that the government can achieve the desired amount of pollution reduction with an emissions fee. Of course, the government could have obtained the same outcome simply by requiring Bart to cut his pollution by e^*. However, the emissions fee has some distinct advantages when there is more than one polluter.

Figure 5.8 Uniform pollution reductions across polluters are not cost effective
If each polluter cuts his pollution by 50 units, Bart's marginal cost is lower than Homer's. Therefore, requiring Bart to reduce more and Homer to reduce less achieves the same reduction goal at a lower total cost. The cost of cutting a given amount of pollution is minimized when the marginal costs of reducing are equal across all polluters.



Let's assume that, in addition to Bart, Homer also pollutes the river in which Lisa fishes. Assume also that it is more costly for Homer to reduce pollution than it is for Bart, so his marginal cost curve is higher. Figure 5.8 shows the marginal cost curves for both Bart (labeled MC_B) and for Homer (labeled MC_H). Suppose that initially they each emit 90 units of pollution per year and that the government has estimated that the efficient amount of pollution reduction is 100 units per year between the two of them. That is, total pollution needs to be reduced from 180 to 80 units per year.

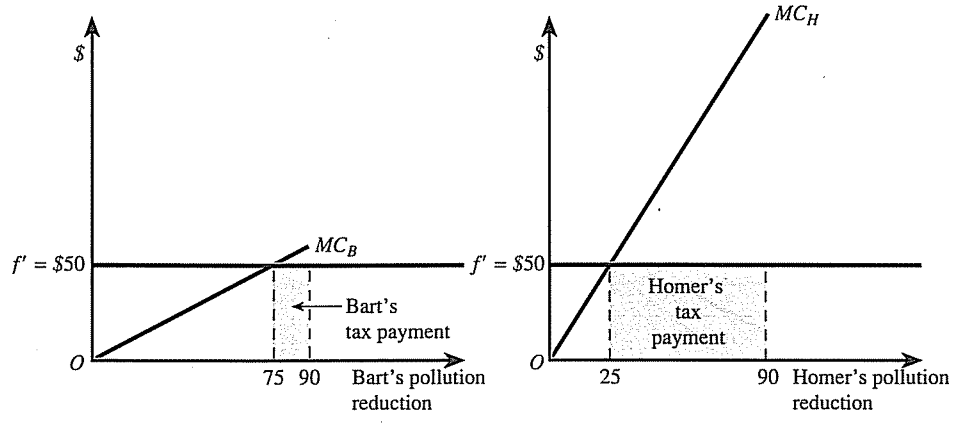
How should this reduction in pollution be divided up between Bart and Homer? One idea is for the government to require each of them to reduce pollution by 50 units per year (meaning each is allowed to pollute 40 rather than 90 units per year). While this would achieve the desired reduction, it would do so at a higher cost than is necessary. To see why, notice in Figure 5.8 that the marginal cost to Homer of reducing the 50th unit is higher than the marginal cost to Bart of reducing the 50th unit (that is, $MC_H > MC_B$). Suppose instead we required Bart to reduce one more unit and allowed Homer to reduce one fewer unit. The total emissions reduction would still be 100 units. However, because the savings to Homer outweighs the increase in cost to Bart, this shift would reduce the overall cost of achieving the 100-unit reduction. As long as the marginal costs differ across the two polluters, one can redistribute the burden so that total costs are reduced. In other words, *the total cost of emissions reduction is minimized only when the marginal costs are equal across all polluters*. An outcome is called **cost effective** if it is achieved at the lowest cost possible. In Figure 5.8, the cost-effective means of achieving the 100-unit reduction is for Bart to cut his pollution by 75 units and for Homer to reduce his by 25 units.

cost effective
A policy that achieves a given amount of pollution reduction at the lowest cost possible.

Some might find the cost-effective outcome inequitable because it requires different levels of responsibility for pollution reduction. After all, why should Homer have a lower burden just because he finds it expensive to reduce pollution? However, with an emissions fee it is possible to achieve the cost-effective outcome *and* reward

Figure 5.9 An emissions fee is cost effective

An emissions fee induces each polluter to reduce pollution up to the point where the marginal cost of reducing equals the level of the fee. This results in equal marginal costs across polluters, which is cost effective.



those who reduce more pollution. To see how, consider Figure 5.9, which replicates the curves from Figure 5.8. Now consider an emissions fee set at f'. For simplicity, let's assume that f' corresponds to a fee of \$50 per unit of pollution. Recall that with an emissions fee, a polluter reduces emissions if the tax savings exceeds the marginal cost of cutting pollution (that is, if $f' > MC$). With this emissions fee, Bart reduces 75 units and Homer reduces 25 units, which is the cost-effective result because at this allocation the marginal costs are equal. From an equity standpoint, Homer is not being rewarded because he has to pay \$50 for each unit of pollution he continues to produce. After cutting his pollution by 25 units, Homer still pollutes 65 units annually and must therefore pay annual taxes equal to \$3,250 (= \$50 × 65). Because Bart reduces his pollution by 75 units, his annual tax liability is only \$750 (= \$50 × 15). In short, the firm that cuts back pollution less isn't really getting away with anything because it has a larger tax liability than if it were to cut back more.

The key advantage of an emissions fee is that it achieves pollution reduction at the lowest possible cost. Notice in Figure 5.9 that for *any* emissions fee, the marginal cost of reduction is the same for Bart and Homer (that is, $MC_B = MC_H$), so we obtain a cost-effective outcome. To be sure, a fee higher than \$50 would lead to more than a 100-unit reduction per year and a fee lower than \$50 would lead to less than a 100-unit annual reduction. But whatever the reduction, the fee achieves it at the lowest cost possible.

Although we have been discussing emissions fees in the context of pollution, it is equally relevant for dealing with other kinds of externalities. We now discuss one such case.

POLICY PERSPECTIVE

Congestion Pricing

On crowded roads and highways, every motorist imposes costs on other motorists by increasing congestion, but no one is forced to take these costs into account. This is a classic externality. Efficiency could be enhanced by an "emissions fee" on driving equal to the marginal congestion costs (wasted gasoline, time, and so on) imposed on other drivers. In order to be efficient, the fee would be adjusted for time and place. Motorists driving through city rush-hour traffic would pay more than those driving in rural settings or in off-peak hours. Winston and Shirley [1998] estimate that such a policy, called **congestion pricing,** would produce a welfare gain for the United States of at least \$3.2 billion per year.

congestion pricing

A tax levied on driving equal to the marginal congestion costs imposed on other drivers.

Some cities have experimented with congestion pricing. Singapore, for example, has electronic tolls that vary according to the time of day. Trondheim, Norway, imposes charges for access to the city center, with the charges varying by the time of day. Single drivers in San Diego can use high-occupation-vehicle lanes for a price that depends on how congested the highway is at the moment.

London recently implemented a form of congestion pricing to deal with its notorious traffic problem. In 2003, the city began levying a fee of £5 (about \$9) for the privilege of driving into the center of the city during peak hours. Compliance is monitored by video cameras that identify the license plates of drivers who fail to pay the fee. Such drivers are then charged a substantial fine. Preliminary estimates indicate that 60,000 fewer cars now enter the city center, allowing for a doubling of average speeds [Kennedy, 2003, p. 44].

Cap-and-Trade

An alternative policy is for the government to require Bart and Homer to submit one government-issued permit for each unit of pollution they emit in a year. In terms of our example, in order to cut pollution from 180 units down to 80 units, the government would therefore issue 80 permits each year. The level of pollution reduction that Bart and Homer achieve individually depends strictly on the number of permits they each own. What's the best way to allocate the permits between Bart and Homer? From an efficiency standpoint, the initial allocation of permits among the polluters does not matter at all.[7] Given our discussion of the Coase Theorem, this should come as no surprise. By allocating permits the government establishes property rights for the air; the assignment of property rights has distributional, not efficiency, consequences. As long as Bart and Homer are allowed to trade the permits with each other, the ultimate outcome is cost effective. A system of tradable pollution permits is known as **cap-and-trade.**

cap-and-trade

A policy of granting permits to pollute, with the number of permits set at the desired pollution level, and allowing polluters to trade the permits.

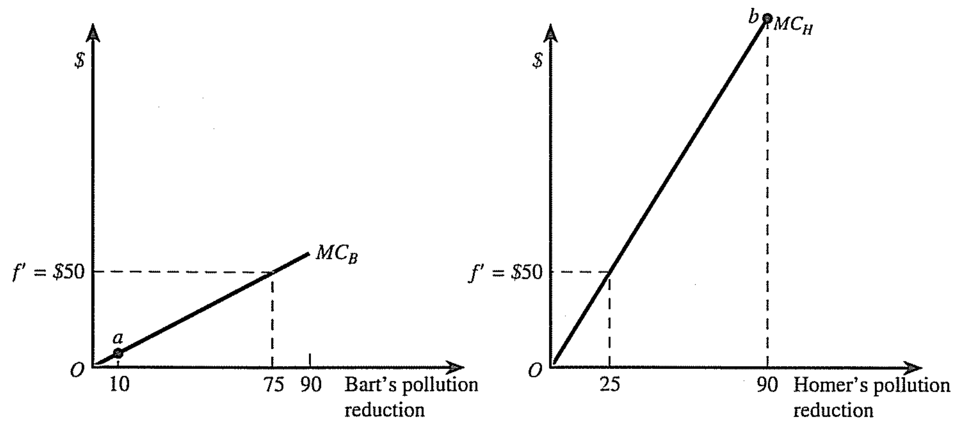
To see why cap-and-trade is cost effective regardless of the initial allocation of permits, consider Figure 5.10, which replicates the marginal cost curves from Figure 5.8. For simplicity, let's assume that Bart receives all 80 permits issued by the government. Because Bart was originally emitting 90 units each year, with 80 permits he now has to reduce emissions by only 10 units, which puts him at point *a* on Figure 5.10. On the other hand, because Homer doesn't have any permits, he must eliminate his pollution. This amounts to a reduction of 90 units, which puts him at point *b* on Figure 5.10. At this outcome, MC_H far exceeds MC_B, so total costs are much higher than they need be—the allocation is not cost effective.

How does trading change this outcome? If Bart were to sell one of his permits to Homer, Bart would have to reduce another unit of pollution. Therefore, he would only sell a permit if the amount he received for it at least covered his cost of reducing the additional unit of pollution. By buying a permit, Homer would be able to pollute one more unit. Therefore, he would only buy a permit if it cost less than the

[7] This only holds if the market for permits is a competitive market (see Hahn [1984]).

Figure 5.10 A cap-and-trade system is cost effective

Bart receives all 80 permits, but there is scope for a bargain between Homer and Bart. Bart will sell permits to Homer until their marginal costs are equal, which is cost effective.



savings he obtained from polluting one more unit. Because the marginal cost to Bart at point a is less than the marginal cost to Homer at point b, there is room for them to bargain, and Bart sells Homer one of his permits. By the same logic, Bart will continue to sell permits to Homer until $MC_B = MC_H$. But recall that $MC_B = MC_H$ defines the cost-effective outcome. We have shown, then, that cap-and-trade is a cost-effective policy. Note also that at this point, the market price for the permits is f' (= $50), which is the same as the emissions fee discussed earlier.

Notice that the same pollution reduction would occur no matter how the government initially allocated the permits between Bart and Homer. Of course, the allocation of permits does affect income distribution, as each of them would like to be sellers of permits rather than buyers of permits. This should come as no surprise—according to the Second Welfare Theorem from Chapter 3, a given efficient outcome can arise from a variety of initial income distributions.

Emissions fees and cap-and-trade systems are symmetrical policies. In our example, an emissions fee set at f' achieves the same pollution reduction from Bart and Homer as a cap-and-trade program in which the government issues 80 permits each year. More generally, for every emissions fee, in theory there is a cap-and-trade system that achieves just the same outcome, and vice versa. However, in practice, there are some differences in the performances of the two systems.

Emissions Fee versus Cap-and-Trade

We now examine several practical differences between an emissions fee and a cap-and-trade system.[8]

Responsiveness to Inflation Recall our earlier example in which the government established an emissions fee set at $50 per unit of pollution. Suppose that the

[8] The list is not exhaustive. For more details, see Gayer and Horowitz [2006].

economy is experiencing inflation. If the fee is not adjusted for changes in the price level each year, then in real terms, its cost to Bart and Homer falls over time. In other words, inflation lowers the real emissions fee. Reexamining Figure 5.9, we see that a lower emissions fee leads to less pollution reduction. In contrast, the cap-and-trade system leads to the same amount of pollution regardless of inflation—with an annual cap of 80 units of pollution, that's the amount of pollution. True, the emissions fee could yield the same result if its level were adjusted each year for inflation. The advantage of cap-and-trade is that no legislative or regulatory action is needed; the adjustment takes place automatically.

Responsiveness to Cost Changes The marginal cost of reducing pollution is likely to change from year to year. The costs might increase if, for example, the demand for the goods being made by the polluting firms increases, thus increasing the opportunity cost of scaling back production. On the other hand, the costs might decrease if firms learn to use their inputs more efficiently, thus generating less waste. To analyze the consequences of cost changes, suppose that a $50 emissions fee levied on Bart and Homer will lead to the efficient level of pollution reduction. Now assume that both Bart's and Homer's marginal costs happen to increase after the imposition of the emissions fee. According to Figure 5.9, with a $50 emissions fee, an increase in the marginal cost curves leads to less pollution reduction (or more pollution). However, under the emissions fee, Bart and Homer are guaranteed to never pay more than $50 to reduce a unit of pollution. No matter how high the cost of reduction gets, they can always opt to pay $50 per unit of pollution instead of reducing another unit of pollution. With the emissions fee, pollution is reduced less than the efficient amount after marginal costs increase.

Assume instead that the government institutes a cap-and-trade program in which the cap is set at the efficient level. If Bart's and Homer's marginal costs increase, Figure 5.10 tells us that the level of pollution reduction stays the same. As mentioned earlier, a cap-and-trade system sets a strict limit on pollution, which does not vary as economic conditions change. However, unlike the emissions fee, the cost of achieving the pollution reduction target can become very high as marginal costs increase. As the marginal cost curves shift up, the market price for permits increases, thus imposing higher costs on Bart and Homer. With cap-and-trade, pollution is reduced more than the efficient amount after marginal costs increase.

In sum, an emissions fee limits the cost of reducing pollution but leads to changes in emissions as economic circumstances change, whereas a cap-and-trade system limits the amount of emissions but leads to changes in the cost of reducing pollution as the economy changes. It is unclear whether it's preferable to set strict limits on the cost of pollution reduction or on the amount of pollution allowed.

One interesting option is to combine the cap-and-trade system with the emissions fee. In this hybrid approach, the government sets up a cap-and-trade system that fixes the amount of allowable pollution. However, the government also makes it known that it will sell as many additional permits as is demanded at a preestablished price. This price, known as the **safety valve price,** can be set rather high so it will only be used if the cost of pollution reduction is much higher than expected. In effect, the safety valve relaxes the pollution cap if the marginal cost of reduction increases beyond a level that policymakers deem acceptable.

safety valve price

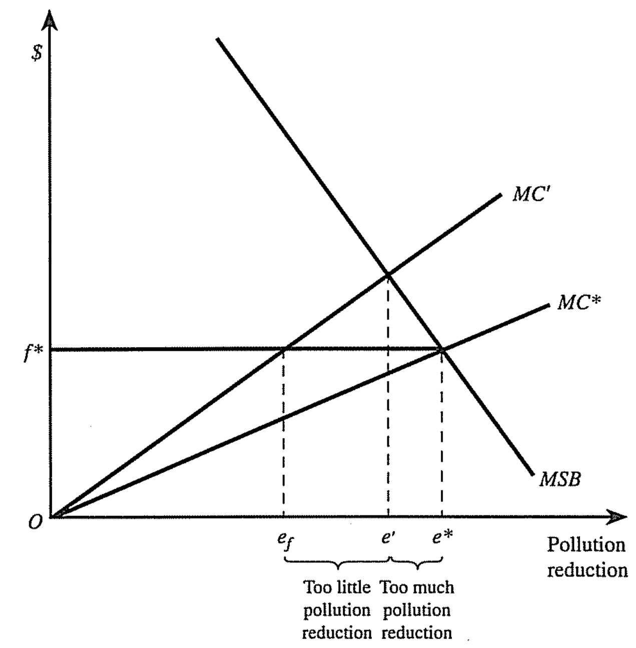
Within a cap-and-trade system, a price set by government at which polluters can purchase additional permits beyond the cap.

Responsiveness to Uncertainty There is great uncertainty about how much it would cost to address many important environmental problems. A prominent

Figure 5.11

Cap-and-trade versus emissions fee when marginal social benefits are inelastic and costs are uncertain

When marginal social benefits are inelastic and costs are higher than expected, cap-and-trade achieves too much pollution reduction and an emissions fee achieves too little pollution reduction. However, cap-and-trade is more efficient.



example is global warming. When such uncertainty exists, an emissions fee and a cap-and-trade program can lead to different results.[9]

For simplicity, let's consider an example with only one polluter. The government is deciding between instituting an emissions fee or a cap-and-trade system. We will consider two cases: one in which the marginal social benefit schedule of reducing pollution is inelastic and one in which it is elastic. With an inelastic schedule, the first units of pollution reduction are highly valuable, but as more reductions occur, their incremental benefit falls off rapidly. With an elastic schedule, the marginal value of each unit of pollution reduction remains fairly constant.

Inelastic Marginal Social Benefit Schedule Figure 5.11 shows an inelastic marginal social benefits schedule. Suppose now that the government is uncertain about the marginal cost of reducing this pollutant. The government's best guess is that the marginal cost schedule is MC^*. However, it could be as high as MC'.

Relying on its best-guess estimate of MC^*, if the government were to use a cap-and-trade system, it would issue enough permits to achieve a reduction of e^*. If MC^* turns out to represent the true costs, then this outcome is efficient. Recall that with a cap-and-trade system, the level of pollution (and thus pollution reduction) is fixed no matter what happens to costs. However, if it turns out that the true marginal cost curve is MC', then the efficient outcome is e', so the cap-and-trade leads to too much pollution reduction (that is, $e^* > e'$). Notice that while the cap-and-trade outcome is inefficient if costs are higher than anticipated, it is not too bad from an efficiency standpoint, because e^* is fairly close to e'.

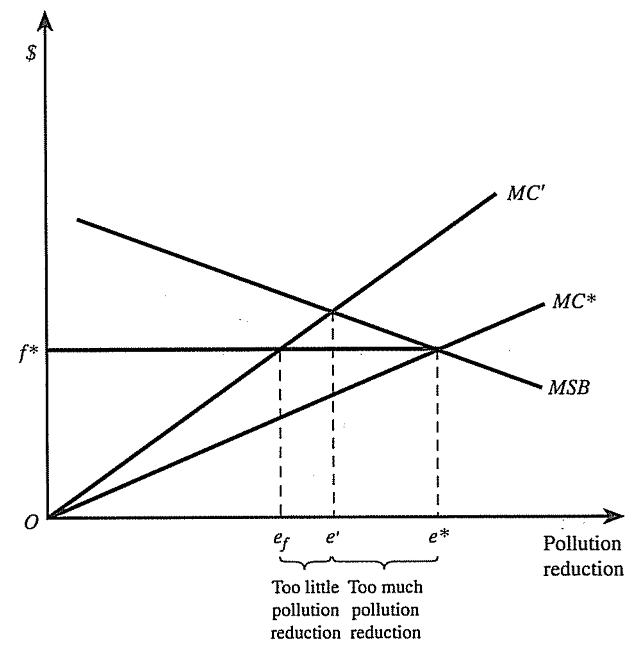
What happens if the government uses an emissions fee under these circumstances? Consider again Figure 5.11. Relying on its best-guess estimate of MC^*, the government

[9] This issue was first explored by Weitzman [1974].

Figure 5.12

Cap-and-trade versus emissions fee when marginal social benefits are elastic and costs are uncertain

When marginal social benefits are elastic and costs are higher than expected, cap-and-trade achieves too much pollution reduction and an emissions fee achieves too little pollution reduction. However, an emissions fee is more efficient.



would set the fee at f^* in order to achieve a reduction of e^*. As before, if MC^* turns out to represent the true costs, then this outcome is efficient. Recall that with an emissions fee, the level of pollution (and thus pollution reduction) changes as the cost curves change. If it turns out that the true marginal cost curve is MC', then the emissions fee will lead to a reduction of e_f, whereas e' is the efficient outcome.

Importantly, while the cap-and-trade outcome in Figure 5.11 was only mildly inefficient if the costs were higher than expected, the emissions fee outcome is highly inefficient because e_f is much smaller than e'. We conclude that *a cap-and-trade system is preferable to an emissions fee when marginal social benefits are inelastic and costs are uncertain*. Intuitively, when marginal social benefits are inelastic, a change in cost has very little effect on the optimal amount of pollution reduction. Therefore, a cap-and-trade system (which fixes the amount of allowable pollution) won't deviate much from the new efficient level. While this analysis has focused on the case where the marginal costs of pollution reduction are higher than expected, similar results can be derived when they are lower than expected. (See Discussion Question 11 at the end of the chapter.)

Elastic Marginal Social Benefit Schedule Figure 5.12 replicates the marginal cost curves from Figure 5.11. However, in this diagram the marginal social benefits of pollution reduction are assumed to be relatively elastic. Just as in the previous example, if the government were to use a cap-and-trade system, it would issue enough permits to achieve a reduction of e^*. If it turns out that the true marginal cost curve is MC', then the efficient outcome is at e', so the cap-and-trade leads to too much pollution reduction (that is, $e^* > e'$).

Figure 5.12 also shows the consequences of an emissions fee. As before, the government would set the fee at f^* in order to reduce emissions by e^*. If MC^* turns out to represent the true costs, then this outcome is efficient. If it turns out that the true marginal cost curve is MC', then the emissions fee leads to a reduction of e_f, whereas e' is the efficient outcome. However, unlike the example with inelastic marginal social benefits, in this case e_f is closer to the efficient outcome than is e^*, the reduction achieved by the cap-and-trade. We conclude that *an emissions fee is preferable to a cap-and-trade system when marginal social benefits are elastic and costs are uncertain.* Intuitively, when marginal social benefits are elastic, a change in cost has a big effect on the optimal amount of pollution reduction. Therefore, a cap-and-trade system (which fixes the amount of allowable pollution) deviates substantially from the new efficient level.

Where does all of this leave us? In a world of uncertainty, we cannot know for sure whether emissions fees or cap-and-trade systems are more efficient. Among other things, it depends on how fast the marginal social benefits of reducing pollution fall with the amount of cleanup. This brings us back to a recurring theme in this chapter. Formulating sensible environmental policy requires an interdisciplinary effort—researchers from a variety of fields are needed to supply information on various technical relationships, including the shape of the marginal social benefit schedule. The tools of economics then allow us to use this information to find efficient solutions to environmental problems.

Distributional Effects Even in the certainty case when cap-and-trade and emissions fees are equivalent from an efficiency standpoint, they can have different distributional consequences. With an emissions fee, polluters must pay taxes for each unit of pollution and the revenue goes to the government. With a cap-and-trade system, if the permits are allocated directly to the polluters for free, then the government receives no revenue. Nonetheless, it is possible for a cap-and-trade system to generate government revenues if the permits are sold directly by the government to polluters rather than allocated for free.

Command-and-Control Regulation

incentive-based regulations
Policies that provide polluters with financial incentives to reduce pollution.

command-and-control regulations
Policies that require a given amount of pollution reduction with limited or no flexibility with respect to how it may be achieved.

technology standard
A type of command-and-control regulation that requires firms to use a particular technology to reduce their pollution.

Emissions fees and cap-and-trade systems are called **incentive-based regulations** because they provide polluters with market incentives to reduce pollution. Basically, each approach increases the opportunity cost of polluting, forcing polluters to take into account the marginal external damages associated with their behavior. Incentive-based regulations allow polluters great flexibility in how to reduce their emissions. Bart might find it cheaper to reduce pollution by cutting his output, while Homer might find it costs less to buy a technology that reduces pollution. Both options are allowed under an incentive-based regulation, because the idea is to find the cheapest feasible way to reduce pollution. In addition to flexibility about how to reduce pollution, there is also flexibility about who should reduce pollution. For example, if the cost of reducing the marginal unit of pollution is cheaper for Bart than for Homer, under a cap-and-trade system Homer buys a permit from Bart. In effect, the built-in flexibility allows Homer to pay Bart to reduce pollution for him. Similarly, under an emissions fee, Bart reduces pollution more than Homer, who instead opts to pay more in taxes.

In contrast to these flexible approaches, the traditional approach to environmental regulation has relied on **command-and-control regulations.** Command-and-control regulations take a variety of forms, but they all are less flexible than incentive-based regulations. A **technology standard** is a command-and-control regulation that requires polluters to install a certain technology to clean up their emissions. Polluters are violating the law if they reduce pollution through any other means, no matter how effective these other means might be. For example, legislation passed several years ago required all new power plants to install "scrubbers" rather than allow them to clean up emissions by switching to cleaner fuels. Unlike incentive-based regulation, a technology standard provides firms no incentive to look for new and cheaper ways to reduce pollution. Why invest in developing a new cleanup technology when the law won't allow you to use it? Therefore, technology standards are unlikely to be cost effective.

performance standard
A command-and-control regulation that sets an emissions goal for each individual polluter and allows some flexibility in meeting the goal.

A **performance standard** is a type of command-and-control regulation that sets an emissions goal for each polluter. The polluter frequently has the flexibility to meet this standard in any way it chooses, so this type of regulation is more cost effective than a technology standard. However, because the performance standard sets a fixed emissions goal for each individual firm, the burden of reducing pollution cannot be shifted to the firms that can achieve it more cheaply. As a result, performance standards are unlikely to be cost effective.

A number of empirical studies have sought to compare the costs of obtaining a given reduction in pollution using a cost-effective approach versus command-and-control. The particular results depend on the type of pollution being considered and the site of the pollution. One summary of these findings shows that command-and-control ranges from 1.07 to 22 times more expensive than the cost-effective approach [*Economic Report of the President, 2003*].

A good example of an inefficient command-and-control approach is provided by the federal government's corporate average fuel economy (CAFE) standards for all new passenger vehicles. These standards dictate the average gasoline mileage that vehicle fleets must attain (27.5 miles per gallon for cars and 20.7 miles per gallon for light trucks such as SUVs). The goal of the policy is to reduce gasoline consumption. CAFE standards have limited flexibility because manufacturers cannot shift the burden among each other to lower overall cost. An alternative approach to reducing gasoline consumption would be to levy a tax on gasoline, which is a form of emissions fee. In a recent analysis, the Congressional Budget Office compared an increase in CAFE standards to an increase in the gasoline tax that achieves the same reduction in gasoline consumption and found that the former would cost about $700 million more per year [Congressional Budget Office, 2004c].

Is Command-and-Control Ever Better? A command-and-control approach can be preferable to an incentive-based approach under certain conditions. The functioning of an incentive-based approach is possible only if the emissions can be monitored. If it is impossible or highly costly to monitor emissions, then the government won't be able to charge a per-unit emissions fee or establish whether a polluter has enough permits to cover its emissions. Some forms of pollution are relatively easy to monitor, such as emissions of sulfur dioxide from power plants. It is more difficult to keep track of other forms, such as agricultural runoff of chemicals, sediment, and nutrients. In such cases, a technology standard might be more efficient, because it is relatively easy to monitor whether a firm has installed the technology.

Another potential problem with incentive-based regulations is that they can lead to high concentrations of pollution in certain local areas. Because an incentive-based system limits total emissions from all sources, it is possible that there will be higher emissions in some areas than others. If emissions concentrate in a localized area, they might cause much higher damages than if they were more diffuse. Localized

hot spots

Localized concentrations of emissions.

concentrations of emissions are known as **hot spots.** A command-and-control standard can avoid hot spots by restricting emissions from each individual pollution source.[10]

THE US RESPONSE

How do real-world responses to externality problems compare to the solutions suggested by theory? In the case of air pollution, the main federal law is the Clean Air Act, which has been amended a number of times.[11] In the 1970 Amendments to the Clean Air Act, Congress charged the Environmental Protection Agency (EPA) with establishing national air quality standards. Congress mandated that the standards were to be uniform across the country and to be set at a level that would "provide an adequate margin of safety." Neither of these conditions is based on concerns with efficiency. Efficient policy would allow standards to vary geographically as costs and benefits vary and would attempt to set standards at the level that maximizes net benefits. Indeed, the courts have ruled that the law prohibits the EPA from even considering costs in setting the standards.

The major environmental regulations of the 1970s relied on the command-and-control approach. For example, the 1970 Amendments to the Clean Air Act established technology standards and performance standards for new sources of air pollution and mandated emission standards for cars, trucks, and buses. The inability to consider costs when setting standards and the reliance on command-and-control regulations has undoubtedly increased the costs of achieving our environmental goals.

Has clean air legislation accomplished its goals? Even ignoring the issue of costs, the record is mixed and difficult to interpret. The six main air pollutants regulated under the Clean Air Act have all decreased since 1970. However, one must be cautious in attributing such decreases to environmental regulation. Perhaps, for example, the improvement was due to technological advances that allow firms to use their inputs more efficiently, thus generating less pollution. EPA analyses of the data suggest that the Clean Air Act was, in fact, instrumental in reducing pollution below levels that otherwise would have occurred [Freeman, 2002, p. 127]. On the other hand, Goklany [1999] provides evidence that air pollution in the United States was declining well before the Clean Air Act. While there is no consensus, many analysts have concluded that the regulations have improved the environment but the performance of the regulations has been disappointing.

We have already shown why a command-and-control approach like the Clean Air Act is likely to be inefficient. Why might it be ineffectual as well? Baumol [1976] emphasizes how the efficacy of regulation depends on the vigilance of the regulator, that is:

> the promptness with which orders are issued, the severity of their provisions, the strength of the regulator's resistance to demands for modifications, his effectiveness in detecting and documenting violations, his vigor and success in prosecuting them, and the severity of the penalties imposed by the judicial mechanism [p. 445].

This is a tall order, especially considering the political pressures under which the regulator is likely to be acting. In contrast, emissions fees "depend not on the

[10] An incentive-based approach can also address hot spots. For example, an emissions fee can charge different tax levels depending on the source of the pollution. Similarly, a cap-and-trade system can require some sources to "cash in" more permits per unit of emissions than other sources. Nonetheless, this does add complexity to the incentive-based approaches.

[11] Excellent summaries of the Act's provisions are in Portney [2000].

watchfulness of the regulator but on the reliable tenacity of the tax collector. They work by inviting the polluter to avoid his payments through the loophole deliberately left to him—the reduction of his emissions" [Baumol, 1976, p. 446].

In addition, the "or else" approach of regulation often backfires. The ultimate threat is to close the polluting facility. In many cases, however, such closure would create major dislocations among workers and/or consumers and is therefore politically difficult. The Texas state legislature once decided that complying with EPA rules for testing cars and trucks for excessive emissions would be too costly. The legislature simply defied the EPA's orders to set up a new system. In the same spirit, when a court in India ordered authorities in Delhi to replace its fleet of 10,000 buses that run on diesel fuel with cleaner natural gas buses, nothing happened. The city authorities simply were not willing to go up against the bus owners, who promised, among other things, to protest by a hunger strike to the death. Indeed, two years after the court's decision, Delhi continued licensing new diesel buses [Dugger, 2001, p. A3].

This is not to say command-and-control regulation is never useful. As discussed earlier, when pollutants are difficult to monitor, it might be the best solution. But in general, command-and-control is probably the source of much of the problems with environmental policy. Why, then, is it so popular? Perhaps legislators like the immediate sense of doing something that enacting regulations gives them, even though more passive measures like creating a market would probably do the job more efficiently. A cynic would argue that the regulatory solution is the result of politicians' desire to have it both ways: Pass noble sounding legislation to please environmentalists, but make it unworkable to keep business happy.

Progress with Incentive-based Approaches

Although the command-and-control approach has dominated US environmental policy, economists' arguments in favor of incentive-based approaches are gaining ground. In particular, several important cap-and-trade programs have been implemented. This section discusses two of them.

POLICY PERSPECTIVE

Cap-and-Trade for Sulfur Dioxide

Acid rain forms when sulfur oxides and nitrogen oxides emitted into the air react with water vapor to create acids. The Acid Rain Trading Program, created as part of the 1990 Amendments to the Clean Air Act, is the most notable US example of an incentive-based approach. It sets a national annual cap on sulfur dioxide emissions. All electric utilities (the main producers of sulfur dioxide) must have an "emissions allowance" for each ton of sulfur dioxide they emit into the atmosphere. The total number of allowances equals the cap. The allowances are initially distributed among existing electric-generating units for free, after which they can be bought and sold, just as in our theoretical model (Figure 5.10).[12] Currently, there are allowances for about 9 million tons per year [Burtraw, 2002, p. 140].

[12] The program sets aside 2.8 percent of allowances each year that are auctioned off. The auction revenue is transferred back pro rata to the electric utilities from whom the auction pool was created.

The trading market for the allowances is very active. The price per allowance ranges between $150 and $200. Interestingly, this is substantially below the price that was originally predicted, implying that hitting the target amount of sulfur dioxide emissions cost less than anyone guessed. Indeed, some estimates suggest that the program saves between $0.9 billion and $1.8 billion per year relative to the costs of a conventional regulatory approach [*Economic Report of the President, 2004*, p. 185]. Our theory predicts that cap-and-trade approaches provide financial incentives for firms to find new technologies for reducing pollution, and this prediction has been borne out. For example, some firms reduced their emissions by combining coals with various sulfur contents to attain intermediate results. Prior to the emissions trading program, such blending was not considered to be technologically practical, but the program gave firms incentives to figure out ways to make it work [Burtraw, 2002, p. 144]. In short, the sulfur dioxide emissions trading experiment has been a success.

Our next example of cap-and-trade programs focuses on rather different kinds of externalities, those that deal with the management of fisheries and wildlife. Fishing areas that are open to all comers are associated with externalities because every fish caught depletes the number available to others and increases the risk that the entire stock will be depleted. A similar problem exists for open-access hunting of wildlife. Like air pollution, the regulation of fisheries and wildlife has moved somewhat away from command-and-control toward incentive-based regulations.

POLICY PERSPECTIVE

Cap-and-Trade to Protect Fisheries and Wildlife

Government regulations in the past have sought to address the problem of overfishing through inefficient command-and-control regulations. For example, in 1978 the Mid-Atlantic Fishery Management Council, authorized by federal legislation, passed a rule that forbade new vessels from fishing for surf clams. Consequently, older vessels simply remained in the fishery longer than they otherwise would have, and overfishing was unchanged. Another example is the halibut fishery, in which the fishing season was progressively reduced in an attempt to address overfishing. This provided an incentive for fishermen to increase the number of vessels in their fleets, to use larger and larger vessels, and to make a mad rush to fish as much as possible within the season, even if the fishing conditions were extremely dangerous.

individual transferable quotas

A cap-and-trade program for fisheries, in which tradable permits are issued to fishermen indicating how many fish they are allowed to catch.

In order to avoid these problems with the regulatory approach, Regional Fishery Councils, authorized by federal legislation, have recently introduced cap-and-trade systems for fisheries, known as **individual transferable quotas** (ITQs). The Councils issue tradable permits to fishermen indicating how many fish they are allowed to catch; the total number of permits equals the total quota for that year. Compliance is monitored in a number of ways, such as dockside inspections [National Research Council, 1999].

The first major US ITQ program was developed in 1989 for surf clams and ocean quahogs (a type of clam). Currently, federal ITQ programs are in effect for Alaska halibut and sablefish, as well as Bering Sea crab. Several states have also instituted ITQ programs. A study of US fisheries by the National Research Council [National Research Council, 1999] found that the ITQs were successful at addressing overfishing and removed the incentive for inefficient fishing practices such as the rush to fish in unsafe conditions. Other countries have also successfully implemented ITQs, including Canada, New Zealand, and Iceland.

The preservation of wildlife gives rise to similar issues—in the absence of property rights or government restrictions, overhunting occurs, sometimes to the point of extinction. In order to conserve elephant populations in Africa, one approach taken is simply to ban hunting. However, the local villagers have no incentive to obey the ban; they hunt anyway (the law is hard to enforce), and the marginal cost to them of each animal killed is effectively zero. A price of zero leads to substantial overhunting. Another approach is to grant individual villagers property rights to the animals, similar to ITQs. In this case, the villagers have an incentive to conserve the herds, because they can make money by selling permission to hunt them. According to Sugg [1996], Kenya banned all hunting in 1977, and its elephant population fell from 167,000 to 16,000 by 1989. In contrast, in 1982, Zimbabwe granted landowners property rights over wildlife; between that time and 1995 its elephant population grew from 40,000 to 68,000. The idea of giving individuals property rights to wild animals on their land has apparently caught on. In southern Africa, many farmers have found it profitable to stop growing food, let their land revert to its natural state, and then charge tourists to view the animals. About 18 percent of the land in the southern third of Africa is now devoted to such ecotourism [Heal, 2001, p. 10].

Sulfur dioxide trading and ITQs are widely seen as success stories. Nevertheless, incentive-based approaches are far from replacing command-and-control regulation for dealing with environmental issues. As the costs of traditional environmental programs continue to increase—it is estimated they already amount to more than 2 percent of GDP—the efficiency of incentive-based approaches may make them more attractive to policymakers.

▶ IMPLICATIONS FOR INCOME DISTRIBUTION

Our main focus so far has been on the efficiency aspects of externalities. Welfare economics indicates that we must also take distributional considerations into account. However, attempts to assess the distributional implications of environmental improvement raise a number of difficult questions.

Who Benefits?

In our simple model, the distribution of benefits is a trivial issue because there is only one type of pollution and one pollution victim. In reality, individuals suffer differently from various externalities. Some evidence suggests that poor neighborhoods tend to have more exposure to air pollution than high-income neighborhoods [Gayer, 2000]. If this is true, lowering the level of air pollution might make the distribution of real income more equal, other things being the same. On the other hand, the benefits of environmental programs that improve recreational areas such as national parks probably benefit mainly high-income families, who tend to be their main users.

Even knowing who suffers from some externality does not tell us the value to them of having it removed. Suppose a high-income family would be willing to pay more for a given improvement in air quality than a low-income family. Then even if a cleanup program reduces more of the *physical* amount of pollution for low- than for high-income families, in *dollar* terms the program can end up favoring those with high incomes.

Who Bears the Cost?

Suppose that large numbers of polluting firms are induced to reduce output by government policy. As these firms contract, the demand for the inputs they employ falls, making the owners of these inputs worse off.[13] Some of the polluters' former workers may suffer unemployment in the short run and be forced to work at lower wages in the long run. If these workers have low incomes, environmental cleanup increases income inequality.

The extent to which the poor bear the costs of environmental protection is a source of bitter controversy. Critics of environmentalism argue that efforts to prevent factories from operating in inner cities have "worsened the economic woes of the mostly poor" people who live there [Ross, 1999, p. A26]. Environmentalists label such assertions "job blackmail" and believe there is no good evidence that the poor are really hurt.

Another consideration is that if polluting firms are forced to take into account marginal social costs, their products tend to become more expensive. From an efficiency point of view, this is entirely desirable, because otherwise prices give incorrect signals concerning full resource costs. Nevertheless, buyers of these commodities are generally made worse off. If the commodities so affected are consumed primarily by high-income groups, the distribution of real income becomes more equal, other things being the same, and vice versa. Thus, to assess the distributional implications of reducing pollution, we also need to know the demand patterns of the goods produced by polluting companies.

It is obviously a formidable task to determine the distribution of the costs of pollution control. In one study, Walls and Hanson [1999] found that the proportional costs of implementing a system of motor vehicle emissions fees would vary inversely with annual income. They calculated that for a family at the bottom of the income distribution, the policy would cost 2.65 percent of income, while for a family at the top, the figure was only 0.35 percent. To the extent such findings generalize to other environmental policies, they pose a dilemma for those who favor both a more equal income distribution and a cleaner environment.

▶ POSITIVE EXTERNALITIES

Most of the focus so far has been on negative externalities. We did observe, however, that spillover effects could also be positive. The analysis of this case is symmetrical. Suppose that when a firm does research and development (R&D), the marginal

[13] More specifically, under certain conditions, those inputs used relatively intensively in the production of the polluting good fall in price. See Chapter 14 under "General Equilibrium Models."

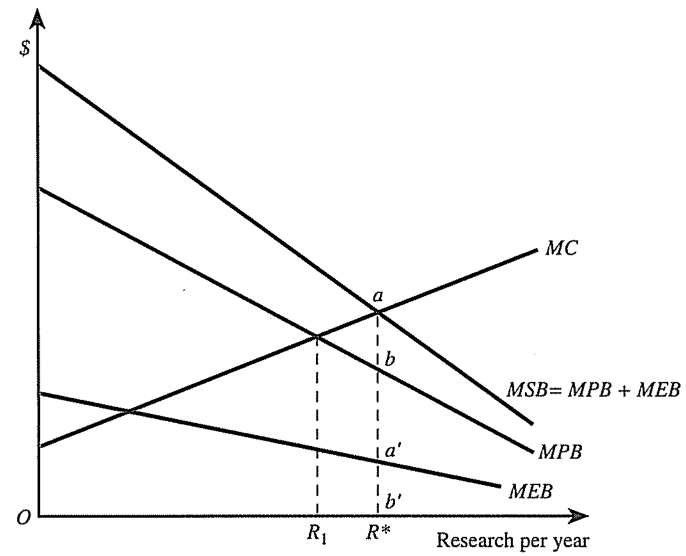


Figure 5.13
Positive externality
With a positive externality, the marginal social benefit is the marginal private benefit plus the marginal external benefit. A profit-maximizing firm produces the output at which marginal private cost equals marginal benefit, R_1. However, efficiency requires that marginal cost equal marginal social benefit, which is at output R^*.

private benefit (*MPB*) and marginal cost (*MC*) schedules are as depicted in Figure 5.13. The firm chooses R&D level R_1, where $MC = MPB$. Assume further that the firm's R&D enables other firms to produce their outputs more cheaply, but that these firms do not have to pay for using scientific results because they become part of general knowledge.[14] In Figure 5.13, the marginal benefit to other firms of each quantity of research is denoted *MEB* (for marginal external benefit). The marginal *social* benefit of research is the sum of *MPB* and *MEB*, and is denoted *MSB*.

Efficiency requires the equality of marginal cost and marginal *social* benefit, which occurs at R^*. Hence, R&D is underprovided. Just as a negative externality can be corrected by a Pigouvian tax, a positive externality can be corrected by a Pigouvian subsidy. Specifically, if the R&D-conducting firm is given a subsidy equal to the marginal external benefit at the optimum—distance *ab* in Figure 5.13—it will produce efficiently.[15] The lesson is clear: When an individual or firm produces positive externalities, the market underprovides the activity or good, but an appropriate subsidy can remedy the situation. Of course, all the difficulties in measuring the quantity and value of the externality still remain. Some research concludes that the private rate of return to R&D is about 10 percent, while the social rate of return is about 50 percent. If these figures are correct, then the positive externalities associated with R&D are substantial.

A Cautionary Note

Many people who have never heard the term *positive externality* nevertheless have a good intuitive grasp of the concept and its policy implications. They understand that if they can convince the government their activities create beneficial spillovers,

[14] Sometimes this type of situation can partially be avoided by patent laws. But in many cases, the results of pure research are not patentable, even though they may be used for commercial purposes.
[15] Note that by construction, $ab = a'b'$.

they may be able to dip into the treasury for a subsidy. Requests for such subsidies must be viewed cautiously for two reasons:

- One way or another, the subsidy has to come from resources extracted from taxpayers. Hence, every subsidy embodies a redistribution of income from taxpayers as a whole to the recipients. Even if the subsidy has good efficiency consequences, its distributional implications may not be desirable. This depends on the value judgments embodied in the social welfare function.
- The fact that an activity is beneficial per se does *not* mean that a subsidy is required for efficiency. A subsidy is appropriate only if the market does not allow those performing the activity to capture the full marginal return. For example, a brilliant surgeon who does much good for humanity creates no positive externality as long as the surgeon's salary reflects the incremental value of his or her services.

We next discuss these points in the context of public policy toward owner-occupied housing.

POLICY PERSPECTIVE

Owner-Occupied Housing

Through a variety of provisions in the US federal income tax code, owner-occupied housing receives a substantial subsidy. (These provisions are detailed in Chapter 17.) This subsidy is currently worth over $114 billion annually [Joint Committee on Taxation, 2006, p. 33]. Can this subsidy be justified? Arguments usually boil down to an assertion that homeownership creates positive externalities. Homeowners take good care of their property and keep it clean, which makes their neighbors better off; hence, the externality. In addition, homeownership provides an individual with a stake in the nation. This increases social stability, another desirable spillover effect.

Careful maintenance of property certainly creates positive externalities, and homeowners are more likely than renters to take care of their property, to garden, and so on [Glaeser and Shapiro, 2002]. But is it homeownership as such that induces this desirable behavior? The beneficial side effects associated with homeownership might just as well be a consequence of the fact that the 66 percent of American families who are homeowners tend to have relatively high incomes. (The median income of homeowners is almost twice that of renters.) Neither is there any evidence that low ownership rates necessarily contribute to social instability. In Switzerland, a nation not known for its revolutionary tendencies, less than a third of the dwellings are owner occupied.

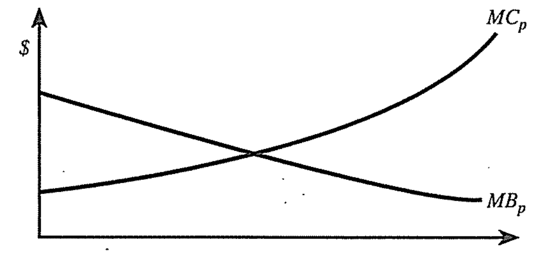
Of course, even if the subsidy does not contribute to correcting an inefficiency, it might be justifiable on equity grounds. But as just noted, homeowners tend to have higher incomes than renters. Thus, only if the distributional objective is to increase income inequality does a subsidy for homeownership make sense from this standpoint.

Summary

- An externality occurs when the activity of one person affects another person outside the market mechanism. Externalities may generally be traced to the absence of enforceable property rights.
- Externalities cause market price to diverge from social cost, bringing about an inefficient allocation of resources.
- The Coase Theorem indicates that private parties may bargain toward the efficient output if property rights are established. However, bargaining costs must be low and the source of the externality easily identified.
- A Pigouvian tax is a tax levied on pollution in an amount equal to the marginal social damage at the efficient level. Such a tax gives the producer a private incentive to pollute the efficient amount.
- A subsidy for pollution not produced can induce producers to pollute at the efficient level. However, subsidies can lead to too much production, are administratively difficult, and are regarded by some as ethically unappealing.
- An emissions fee (a tax levied on each unit of pollution) achieves a given amount of pollution reduction at the lowest feasible cost.
- A cap-and-trade system grants permits to pollute, but allows the permits to be traded. It also achieves a given amount of pollution reduction at the lowest feasible cost.
- Command-and-control regulations are less flexible than incentive-based regulations, and are therefore likely to be costlier.
- Positive externalities generally lead to underprovision of an activity. A subsidy can correct the problem, but care must be taken to avoid wasteful subsidies.

Discussion Questions

1. According to former Vice President Al Gore, "Classical economics defines productivity narrowly and encourages us to equate gains in productivity with economic progress. But the Holy Grail of progress is so alluring that economists tend to overlook the bad side effects that often accompany improvements" [Miller, 1997, p. A22]. Discuss whether or not this is a fair characterization of "classical economics." Gore also stated that we need to take "bold and unequivocal action . . . [to] make the rescue of the environment the central organizing principle for civilization." Suppose that you were a policymaker trying to decide what to do about automobile emissions. How might you use Gore's dictum as a framework for making your decision?
2. In the following figure, the number of parties that Cassanova gives per month is measured on the horizontal axis, and dollars are measured on the vertical. MC_p is the marginal cost of providing parties and MB_p is Cassanova's marginal benefit schedule from having parties.
   a. Graphically, show how many parties Cassanova will host.
   b. Suppose there is a fixed marginal external benefit, $\$b$, per party to Cassanova's friends. Illustrate this on your graph.
   c. What is the socially (no pun intended) optimal level of parties? How could the Social Committee induce Cassanova to throw this number?
   d. On your graph, show the optimal subsidy per party and the total amount paid to Cassanova. Who gains and loses under this plan?



3. For each of the following situations, is the Coase Theorem applicable? Why or why not?
   a. A farmer who grows organic corn is at risk of having his crop contaminated by genetically modified corn grown by his neighbors.
   b. In Brazil it is illegal to catch and sell certain tropical fish. Nevertheless, in some remote parts of the Amazon River, hundreds of divers come to capture exotic fish for sale on the international black market. The presence of so many divers is depleting the stock of exotic fish.
   c. In the state of Washington, many farmers burn their fields to clear the wheat stubble and prepare for the next planting season. Nearby city-dwellers complain about the pollution.
   d. Users of the Internet generally incur a zero incremental cost for transmitting information. As a consequence, congestion occurs, and users are frustrated by delays.
4. Some observers have argued that importing oil makes the United States hostage to the policies of Saudi Arabia and other countries in the Middle East. This complicates US foreign policy.
   a. Explain why an externality is present in this situation.
   b. Propose a Pigouvian tax to deal with the externality.
   c. Some economists want to curb domestic gasoline consumption but are wary of giving the government substantially more revenues than it already has. As an alternative, Feldstein [2006b, p. A10] suggested a system of tradable gasoline rights (TGR):

   "In a system of tradable gasoline rights, the government would give each adult a TGR debit card. The gasoline pumps at service stations that now read credit cards and debit cards would be modified to read these new TGR debit cards as well. Buying a gallon of gasoline would require using up one tradable gasoline right as well as paying money. The government would decide how many gallons of gasoline should be consumed per year and would give out that total number of TGRs. In 2006, Americans will buy about 110 billion gallons of gasoline. . . . To reduce total consumption by 5%, [government] would cut the number of TGRs to 104.5 billion."

   Draw a diagram to illustrate how the price of the tradable gasoline rights would be determined. Suppose that the market price per voucher were 75 cents. How would this change the opportunity cost of buying a gallon of gasoline?
5. In India, a drug used to treat sick cows is leading to the death of many vultures that feed off of dead cattle. Before the decrease in the number of vultures, they sometimes used to smash into the engines of jets taking off from New Delhi's airports, posing a serious threat to air travelers. However, the decline of the vulture population has led to a sharp increase in the populations of rats and feral dogs, which are now the main scavengers of rotting meat [Gentleman, 2006, p. A4]. There have been calls for a ban on the drug used to treat the cows.

   Identify the externalities that are present in this situation. Comment on the efficiency of banning the drug. How would you design an incentive-based regulation to attain an efficient outcome?
6. In California, drivers of hybrid cars are permitted to use the dedicated high-occupancy-vehicle (HOV) lanes on the highways. Given the recent increase in purchases of hybrids, these HOV lanes are becoming increasingly clogged, which leads to an increase in gasoline use and in harmful emissions. Describe an alternative policy for addressing problems with traffic congestion.
7. The Finger Lakes region of New York State attracts tourists who wish to sample its superb wines. In recent years, hog-raising farms—some with more than a thousand hogs—have taken root in the region. The smells emanating from the massive amounts of pig manure adversely affect the tourism. "Wine and swine, in other words, do not mix" [Chen, 2001, p. L1].

   Imagine that the Little Pigs (LP) hog farm is situated near the Tipsy vineyard. The following table shows, for each level of LP's output, the marginal cost of a hog, the marginal benefit to LP, and the marginal damage done to Tipsy:

Output	MC	MB	MD
1	3	13	5
2	6	13	7
3	10	13	9
4	13	13	11
5	19	13	13
6	21	13	15

   a. How many hogs does LP produce?
   b. What is the efficient number of hogs?
   c. The owner of LP gets tired of Tipsy's complaints about her hog farm, and she buys out Tipsy. After the merger, how many hogs does LP produce?
   d. How does the merger affect the sum of the profits earned by LP and Tipsy?
8. The private marginal benefit for commodity X is given by $10 - X$, where X is the number of units consumed. The private marginal cost of producing X is constant at \$5. For each unit of X produced, an external cost of \$2 is imposed on members of society. In the absence of any government intervention, how much X is produced? What is the efficient level of production of X? What is the gain to society involved in moving from the inefficient to the efficient level of production? Suggest a Pigouvian tax that would lead to the efficient level. How much revenue would the tax raise?
9. A deeply held belief in Europe is that university education should be financed almost entirely by the government. In France, undergraduates pay about \$400 per year in tuition; in Germany, federal law explicitly forbids public universities to charge tuition. However, European governments typically don't provide much money for universities, leading to problems with maintaining quality. In response, some observers want to start charging students substantial amounts of tuition. One German official responded that "one of the prime rights of humanity is to have a free university education." In the same way, a Labor member of the British parliament argued that "Introducing a market into higher education is something the Labor Party should not be doing" [Lyall, 2003, p. A3]. Discuss the efficiency and equity consequences of a system of taxpayer-financed higher education.
10. Suppose that two firms emit a certain pollutant. The marginal cost of reducing pollution for each firm is as follows: $MC_1 = 300e_1$ and $MC_2 = 100e_2$, where e_1 and e_2 are the amounts (in tons) of emissions reduced by the first and second firms, respectively. Assume that in the absence of government intervention, Firm 1 generates 100 units of emissions and Firm 2 generates 80 units of emissions.
    a. Suppose regulators decide to reduce total pollution by 40 units. In order to be cost effective, how much should each firm cut its pollution?
    b. What emissions fee should be imposed to achieve the cost-effective outcome? How much would each firm pay in taxes?
    c. Suppose that instead of an emissions fee, the regulatory agency introduces a tradable permit system and issues 140 permits, each of which allows the emission of one ton of pollution. Firm 1 uses it political influence to convince the regulatory agency to issue 100 permits to itself and only 40 permits to Firm 2. How many, if any, permits are traded between the firms? What is the minimum amount of money that must be paid (total) for these permits? By how many tons does each firm end up reducing its pollution?
11. Figure 5.11 demonstrates the efficiency implications of using cap-and-trade versus an emissions fee when costs are higher than expected and marginal social benefits are inelastic. Figure 5.12 does the same thing under the assumption of elastic marginal social benefits. Now consider the case where marginal costs turn out to be *lower* than anticipated. For both cap-and-trade and an emissions fee, show whether there is too much or too little emissions reduction. Which approach is more efficient when marginal social benefits are inelastic and when they are elastic?