CHAPTER 18

Externalities and Public Goods

In this chapter we study *externalities*-the effects of production and consumption activities not directly reflected in the market-and *public goods*-goods that benefit all consumers, but that the market either undersupplies or does not supply at all. Externalities and public goods are important sources of market failure and thus raise serious public policy questions. For example, how much effluent, if any, should firms be allowed to dump into rivers and streams? How strict should automobile emission standards be? How much money should the government spend on national defense? education? basic research? public television?

When externalities are present, the price of a good need not reflect its social value. As a result, firms may produce too much or too little, so that the market outcome is inefficient. We begin by describing externalities and showing exactly how they create market inefficiencies. We then evaluate remedies; some remedies involve government regulation,while others rely primarily on bargaining among individuals or on the legal right of those adversely affected to sue those who create the externality.

Next, we analyze public goods. The marginal cost of providing a public good to an additional consumer is zero, and people cannot be excluded from consuming it. We distinguish between those goods that are difficult to provide privately and those that could have been provided by the market. We conclude by describing the problem policymakers face when trying to decide how much of a public good to provide.

18.1 *Externalities*

Externalities can arise between producers, between customers, or between consumers and producers. Externalities can be *negative*-when the action of one party imposes costs on another party-or *positive*-when the action of one party benefits another party.

A negative externality occurs,for example, when a steel plant dumps its waste in a river that fishermen downstream depend on for their daily catch. The more waste the steel plant dumps in the river, the fewer fish will be supported. The firm, however, has no incentive to account for the external costs that it imposes on fishermen when making its production decision. A positive externality occurs when a home owner repaints her house and plants an attractive garden. All the neighbors benefit from this activity, yet the home owner's decision to repaint and landscape probably did not take these benefits into account.

Negative Externalities and Inefficiency

Because externalities are not reflected in market prices, they can be a source of economic inefficiency. To see why, let's take our example of a steel plant dumping waste in a river. Figure 18.la shows the production decision of the steel plant in a competitive market, and Figure 18.1b shows the market demand and supply curves, assuming that all steel plants generate similar externalities. We assume that the firm has a fixed-proportions production function, so that it cannot alter its input combinations; effluent can be reduced only by lowering output. We will analyze the nature of the externality in two steps: first when only one steel plant pollutes, and then when all steel plants pollute in the same way.

The price of steel is P_1, at the intersection of the demand and supply curves in Figure 18.Ib. The MC curve in (a) gives a typical steel firm's marginal cost of production. The firm maximizes profit by producing output q_1, at which marginal cost is equal to price (which equals marginal revenue because the firm takes price as given).As the firm's output changes, however, the external cost imposed on fishermen downstream also changes. This external cost is given by the *marginal external cost* (*MEC*) *curve* in Figure 18.1a. The curve is upward sloping for most forms of pollution because as the firm produces additional output and dumps additional effluent in the river, the incremental harm to the fish industry increases.

From a social point of view, the firm produces too much output. The efficient output is the level at which the price of the product is equal to the *marginal social cost* of production-the marginal cost of production *plus* the marginal external cost of dumping effluent. In Figure 18.1a, the marginal social cost-curve is obtained by adding marginal cost and marginal external cost for each

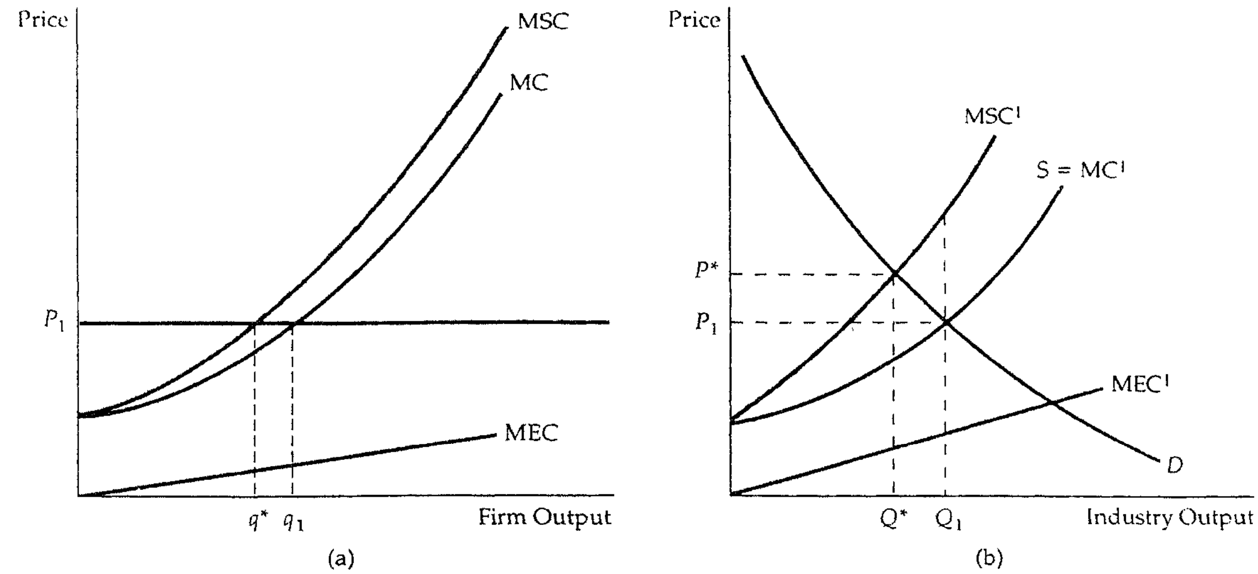

FIGURE 18.1 External Cost. When there are negative externalities, the marginal social cost MSC is higher than the marginal private cost MC. The difference is the marginal external cost MEC. In (a), a profit-maximizing firm produces at q_1, where price is equal to MC. The efficient output is q^*, at which price equals MSC. In (b), the industry competitive output is Q_1, at the intersection of industry supply MC_1 and demand D. However, the efficient output Q^* is lower, at the intersection of demand and marginal social cost MSC_1.

level of output (i.e., MSC = MC + MEC). The marginal social cost-curve MSC intersects the price line at the output q^*. Because only one plant is dumping effluent into the river in this case, the market price of the product is unchanged. However, the firm is producing too much output (q_1 instead of q^*) and generating too much effluent.

Now consider what happens when all steel plants dump their effluent into rivers. In Figure 18.1b, the MC_1 curve is the industry supply curve. The marginal external cost associated with the industry output, MEC_1, is obtained by summing the marginal cost of every person harmed at each level of output. The MSC_1 curve represents the sum of the marginal cost of production and the marginal external *cost for all steel firms.* As a result, $MSC_1 = MC_1 + MEC_1$.

Is industry output efficient when there are externalities? As Figure 18.1b shows, the efficient industry output level is the one at which -the marginal benefit of an additional unit of output is equal to the marginal social cost. Because the demand curve measures the marginal benefit to consumers, the efficient output is Q^*, at the intersection of the marginal social cost MSC_1 and demand D curves. The competitive industry output, however, is at Q_1, the intersection of the demand curve and the supply curve, MC_1. Clearly, industry output is too high.

In our example, each unit of output results in some effluent being dumped. Therefore, whether we are looking at one firm's pollution or the entire industry's, the economic efficiency is the excess production that causes too much effluent to be dumped in the river. The source of the inefficiency is the incorrect pricing of the product. The market price P_1 in Figure 18.1b is too low-it reflects the-firms' marginal private cost of production, but not the marginal *social* cost. Only at the higher price P^* will steel firms produce the efficient level of output.

What is the cost to society of this inefficiency? For each unit produced above Q^*, the social cost is given by the difference between the marginal social cost and the marginal benefit (the demand curve). As a result, the aggregate social cost is shown in Figure 18.1b as the tan-shaded triangle between MSC_1, D, and output Q_1.

Externalities generate long-run as well as short-run inefficiencies. In Chapter 8 we saw that firms enter a competitive industry whenever the price of the product is above the *average cost* of production, and exit whenever price is below average cost. In long-run equilibrium, price is equal to (long-run) average cost. When there are negative externalities, the average private cost of production is less than the average social cost. As a result, some firms remain in the industry even when it would be efficient for them to leave. Thus, negative externalities encourage too many firms to remain in the industry.

Positive Externalities and Inefficiency

Externalities can also result in too little production, as the example of home repair and landscaping shows. In Figure 18.2, the horizontal axis measures the home owner's investment (in dollars) in repairs and landscaping. The marginal cost curve for home repair shows the cost of repairs as more work is done on the house; it is horizontal because this cost is unaffected by the amount of repairs. The demand curve D measures the marginal private benefit of the repairs to the home owner. The home owner will choose to invest q_1 in repairs, at the intersection of her demand and marginal cost curves. But repairs generate external benefits to the neighbors, as the *marginal external benefit* curve, MEB, shows. This curve is downward sloping in this example because the marginal benefit is large for a small amount of repair but falls as the repair work becomes extensive.

The marginal social benefit curve MSB is calculated by adding the marginal private benefit and the marginal external benefit at every level of. output. In short, $MSB = D + MEB$. The efficient level of output q^*, at which the marginal social benefit of additional repairs is equal to the marginal cost of those repairs, is found at the intersection of the MSB and MC curves. The inefficiency arises because the home owner doesn't capture all the benefits of her investment in repairs and landscaping. As a result, the price Pi is too" high to encourage her to invest in the socially desirable level of house repair. A lower price P^* is required to encourage the efficient level of supply, q^*.

Another example of a positive externality is the money that firms spend on research and development (R&D). Often the innovations resulting from re-

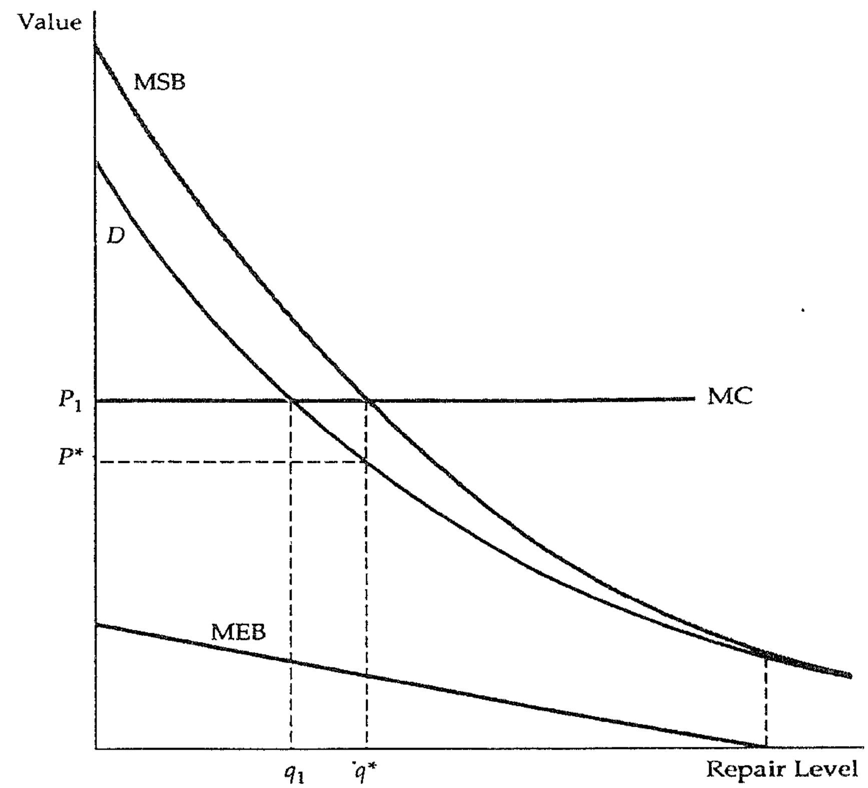

FIGURE 18.2 External Benefits. When there are positive externalities, marginal social benefits MSB are higher than marginal benefits *D*. The difference is the marginal external benefit MEB. A self-interested home owner invests q_1 in repairs, determined by the intersection of the marginal benefit curve *D* and the marginal cost curve MC. The efficient level of repair q^* is higher, and is given by the intersection of the marginal social benefit and marginal cost curves.

search cannot be protected from other firms. Suppose, for example, that a firm designs a new product. If that design can be patented, the *firm* might earn a large profit by manufacturing and marketing the new product. If the new design can be closely imitated by other firms, however, those firms can compete away some of the developing firm's profit. There is then little reward for doing R&D, and the market is likely to underfund it.

18.2 *Ways of Correcting Market Failure*

How can the inefficiency resulting from an externality be remedied? If the firm that generates the externality has a fixed-proportions production technology, the externality can be reduced only by encouraging the firm to produce less.

This can be achieved through an output tax, as we saw in Chapter 8. Fortunately, most firms can substitute among inputs in the production process by altering their choice of technology. For example, a manufacturer can add a scrubber to its smokestack to reduce its emissions.

Consider a firm that sells its output in a competitive market. The firm emits pollutants that damage air quality in a neighborhood. The firm can reduce its emissions, but only at a cost. Figure 18.3 illustrates this. The horizontal axis represents the level of factory emissions. An emissions level of 26 units corresponds to the firm's profit-maximizing output. The curve labeled MSC represents the *marginal social cost of emissions.* This social cost curve represents the increased harm associated with the emissions of the factory, and is therefore equivalent to the MEC curve described earlier. The MSC curve slopes upward because the *marginal* cost of the externality is higher the more extensive it is. (Evidence from studies of the effects of air and water pollution suggests that small levels of pollutants generate little harm. However, the harm increases substantially as the level of pollutants increases.)

The curve labeled MCA is the *marginal cost of abating emissions.* It measures the additional cost to the firm of installing pollution control equipment. The MCA curve is downward sloping because the marginal cost of reducing emissions is low when the reduction has been slight, and high when it has been substantial. (A slight reduction is inexpensive-the firm can reschedule production so the greatest emissions occur at night, when few people are out-

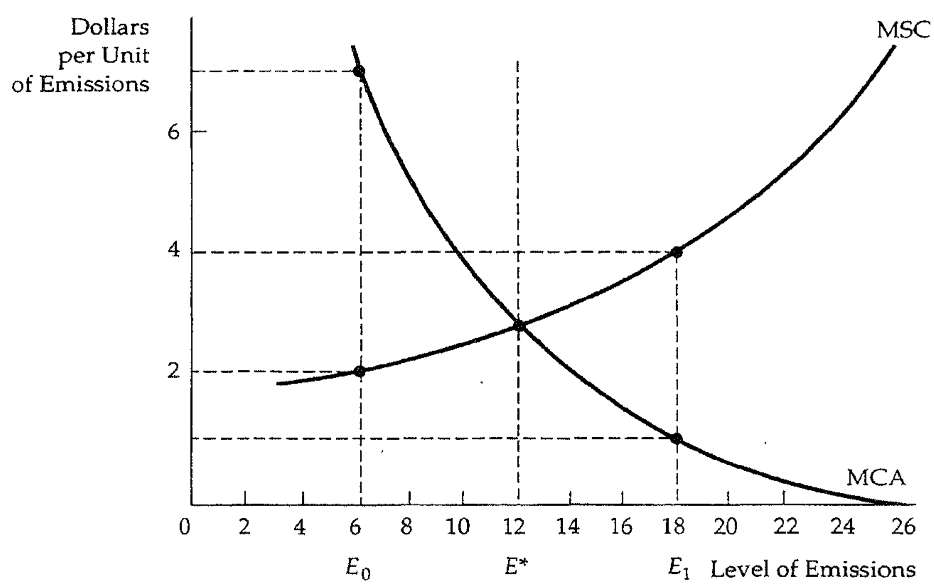

FIGURE 18.3 The Efficient Level of Emissions. The efficient level of factory emissions is the level that equates the marginal social cost of emissions MSC to the benefit associated with lower abatement costs MCA. The efficient level of 12 units is E^*.

side-but substantial reductions require costly changes in the production process.)

The efficient level of emissions, 12 units, is at point E^*, where the marginal social cost of emissions, $3, is equal to the marginal cost of abating emissions. At E^*, the sum of the firm's abatement costs and of the social costs is minimized. Note that if emissions are lower than E^*, say, E_0, the marginal cost of abating emissions, $7, is greater than the marginal social cost, $2, so emissions are too low. However, if the level of emissions is E_1, the marginal social cost, $4, is greater than the marginal benefit, $1, so emissions are too high.

We can encourage the firm to reduce emissions to E^* in three ways: emissions standards, emissions fees, and transferable emissions permits.

An Emissions Standard

An *emissions standard* is a legal limit on how much pollutant a firm can emit. If the firm exceeds the limit, it can face monetary and even criminal penalties. In Figure 18.4, the efficient emission standard is 12 units, at point E^*. The firm will be heavily penalized for emissions greater than this.

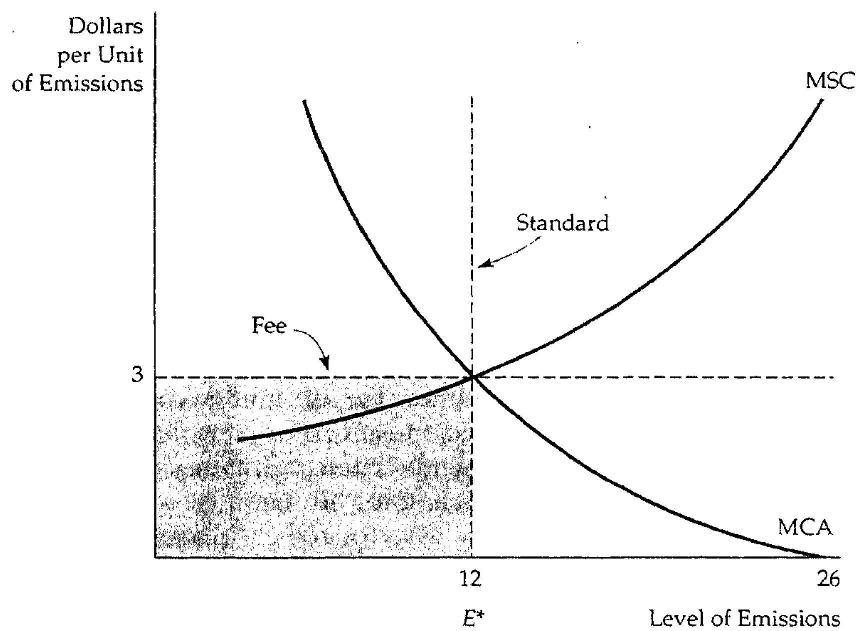

FIGURE 18.4 Standards and Fees. The efficient level of emissions at E^* can be achieved either through an emissions fee or an emissions standard. Facing a fee of $3 per unit of emissions, a firm reduces emissions to the point at which the fee is equal to the marginal benefit. The same level of emissions reduction can be achieved with a standard that limits emissions to 12 units.

The standard ensures that the firm produces efficiently. The firm meets the standard by installing pollution abatement equipment. The increased abatement expenditure will cause the firm's average cost curve to rise (by the average cost of abatement). Firms will find it profitable to enter the industry only if the price of the product is greater than the average cost of production plus abatement-the efficient condition for the industry. [1]

An Emissions Fee

An *emissions fee is* a charge levied on each unit of a firm's emissions. A $3 emissions fee will generate efficient behavior by our factory, as Figure 18.4 shows. With this fee, the firm minimizes its costs by reducing emissions from 26 to 12 units. To see why, note that the first unit of emissions can be reduced (from 26 to 25 units of emissions) at very little cost (the marginal cost of additional abatement is close to zero). Therefore, for very little cost, the firm can avoid paying the $3 per unit fee. In fact, for all levels of emission above 12 units, the marginal cost of abatement is less than the emissions fee, so it pays to reduce emissions. Below 12 units, however, the marginal cost of abatement is greater than the fee, so the firm will prefer to pay the fee rather than reduce emissions further. The firm will' therefore pay a total fee given by the gray-shaded rectangle and will incur a total abatement cost given by the tan-shaded triangle under the MCA curve to the right of $E = 12$. This cost is less than the fee the firm would pay if it did not reduce its emissions at all.

Standards Versus Fees

The United States has historically relied on standards to regulate emissions. However, other countries, such as Germany, have used fees successfully. Which method is better?

There are important differences between standards and fees when the policymaker has incomplete information and when it is costly to regulate firms' emissions. To understand these differences, let's suppose that because of administrative costs the agency that regulates emissions must charge the same fee or set the same standard for all firms.

First, let's examine the case for fees. Consider two firms that are located so that the marginal social cost of emissions is the same no matter which firm reduces its emissions. Because the firms have different abatement costs, however, their marginal cost of abatement curves are not the same. Figure 18.5 shows why emissions fees are preferable to standards in this case. MCA_1 and MCA_2 represent the marginal cost of abatement curves for the two firms. Each firm initially generates 14 units of emissions. Suppose we want to reduce total

[1] This assumes that the social costs of emissions do not change over time. If they do, the efficient standard will also change.

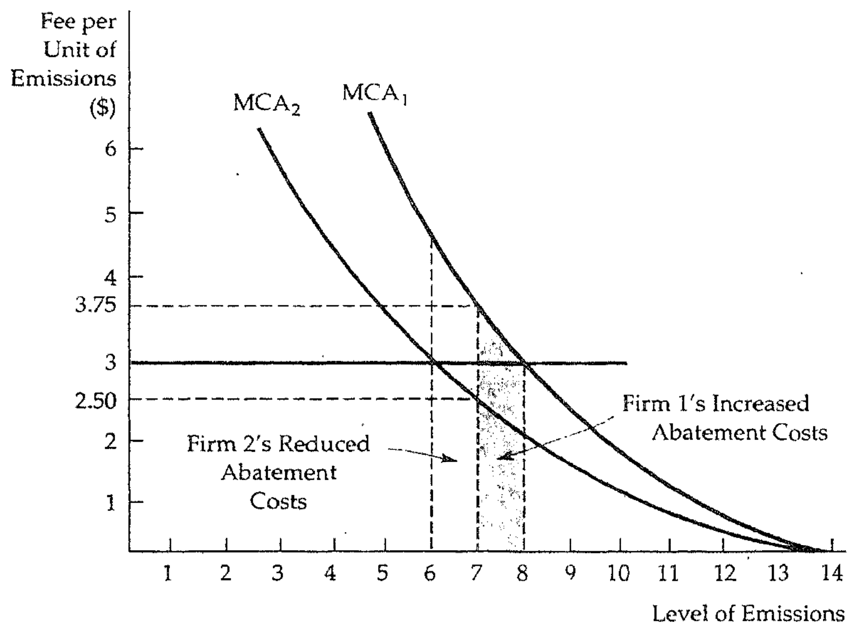

FIGURE 18.5 The Case for Fees. With limited information, a policymaker maybe faced with the choice of either a single emissions fee or a single emissions standard for all firms. The fee of $3 achieves an emissions level of 14 units more cheaply than a 7-unit-per-firm emissions standard. With the fee, the firm with a lower abatement cost curve (Firm 2) reduces emissions more than the firm with a higher cost curve (Firm 1).

emissions by 14 units. Figure 18.5 shows that the cheapest way to do this is to have Firm 1 reduce emissions by 6 units and Firm 2 reduce emissions by 8 units. With these reductions,both firms have marginal costs of abatement of $3. But consider what happens if the regulatory agency asks both firms to reduce their emissions by 7 units. Then the marginal cost of abatement of Firm 1 increases from $3 to $3.75, and the marginal cost of abatement of Firm 2 decreases from $3 to $2.50. This cannot be cost-mmimizing because the second firm can reduce emissions more cheaply than the first. Only when the marginal cost of abatement is equal for both firms will emissions be reduced by 14 units at minimum cost.

Now we can see why an emissions fee ($3) might be preferable to an emissions standard (7 units). With a $3 emissions fee. Firm 1 will reduce emissions by 6 units and Firm 2 by 8 units, the efficient outcome. By contrast, with the emissions standard. Firm 1 incurs additional abatement costs given by the gray-shaded area between 7 and 8 units of emission. But Firm 2 enjoys reduced abatement costs given by the red-shaded area between 6 and 7 units of emission. Clearly, the added abatement costs to Firm 1 are larger than the reduced costs to Firm 2. The emissions fee thus achieves the same level of emissions at a lower cost than the equal per-firm emissions standard.

In general, fees can be preferable to standards for several reasons. First, when standards must be assessed equally for all firms, fees achieve the same emissions reduction at a lower cost. Second, fees give a firm a strong incentive to install new equipment that would allow it to reduce emissions *even further.* Suppose the standard requires that each firm reduce its emission by 6 units, from 14 to 8. Firm 1 is considering installing new emissions devices that would lower its marginal cost of abatement from MCA_1 to MCA_2. If the equipment is relatively inexpensive,the firm will install it because this equipment would lower the cost of meeting the standard. However, a $3 emission fee would provide a greater incentive for the firm to reduce emissions. With the fee, not only will the firm's cost of abatement be lower on the first 6 units of reduction, it will also be cheaper to reduce emissions by 2 more units (because the emissions fee is greater than the marginal abatement cost for emissions levels between 6 and 8).

Now let's examine the case for standards by looking at Figure 18.6. The marginal social cost curve is very steep, while the marginal benefit curve is relatively flat. The efficient emissions fee is $8. But suppose that because of limited information a lower fee of $7 is charged (this amounts to a 1/8 or 12.5

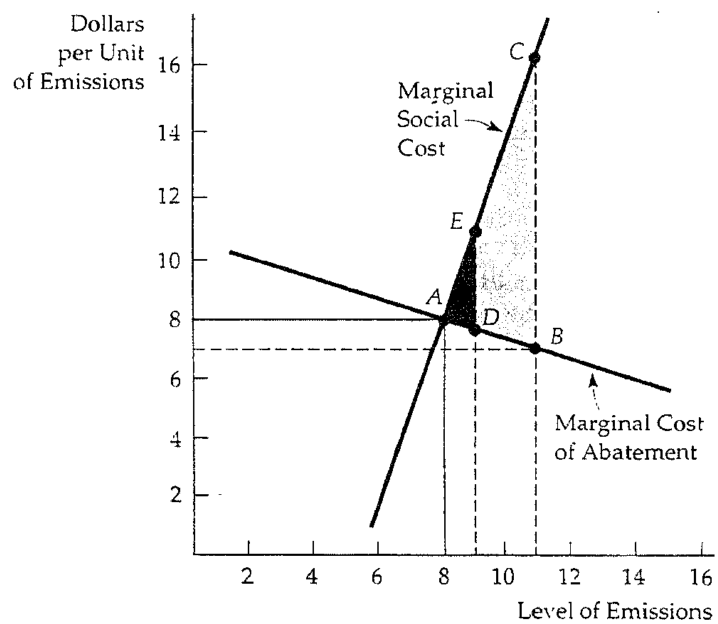

FIGURE 18.6 The Case for Standards. When the government has limited information about the costs and benefits of pollution abatement, either a standard or a fee may be preferable. The standard is preferable when the marginal social cost curve is steep and the marginal abatement cost curve is relatively flat. Here a 12.5 percent error in setting the standard leads to extra social costs of triangle *ADE*. The same percentage error in setting a fee would result in excess costs of *ABC*.

percent reduction). Because the MCA curve is flat, the firm's emissions will be increased from 8 to 11 units. This lowers the firm's abatement costs somewhat, but because the MSC curve is steep, there will be substantial additional social costs. The increase in social costs, less the savings in abatement costs, is given by the entire red-shaded (light and dark) triangle *ABC*.

What happens if a comparable error is made in setting the standard? The efficient standard is 8 units of emissions. But suppose the standard is relaxed by 12.5 percent, from 8 to 9 units. This will lead to an increase in social costs and a decrease in abatement costs as before. But the net increase in social costs, given by the darkly shaded triangle *ADE*, is substantially smaller than before.

This example illustrates the difference between standards and fees. When the marginal social cost curve is relatively steep and the marginal cost of abatement curve relatively flat, the cost of not reducing emissions is high, and a standard is preferable to a fee. With incomplete information, standards offer more certainty about emissions levels but leave the costs of abatement uncertain. Fees, on the other hand, offer certainty about the costs of abatement but leave the reduction of emissions levels uncertain. Which policy is preferable depends, therefore, on the nature of uncertainty and on the shapes of the cost curves.

Transferable Emissions Permits

Suppose we want to reduce emissions, but because of uncertainty, we don't want to rely on an emissions fee. We also want to avoid imposing high costs on the firms that reduce their emissions the most. We can reach these goals by using *transferable emissions permits.* Under this system, each firm must have a permit to generate emissions. Each permit specifies exactly how much the firm is allowed to emit. Any firm that generates emissions that are not allowed by permit is subject to substantial monetary sanctions. Permits are allocated among firms, with the number of permits chosen to achieve the desired maximum level of emissions. The permits are marketable-they can be bought and sold.

Under the transferable emissions permit system, the firms least able to reduce emissions are those that purchase permits. Thus,suppose the two firms in Figure 18.5 were given permits to emit up to 7 units. Firm 1, facing a relatively high marginal cost of abatement, would pay up to $3.75 to buy a permit for one unit of emissions, but the value of that permit is only $2.50 to Firm 2. Firm 2 should therefore sell its permit to Firm 1 for a price between $2.50 and $3.75.

If there are enough firms and permits, a competitive market for the permits will develop. In market equilibrium, the price of a permit equals the marginal cost of abatement for all firms; otherwise a firm will find it advantageous to buy more permits. The level of emissions chosen by the government will be achieved at minimum cost. Those firms with relatively low marginal cost of abatement curves will be reducing emissions the most, and those firms with relatively high marginal cost of abatement curves will be buying more permits and reducing emissions the least.

Marketable emissions permits create a market for externalities. This market approach is appealing because it combines some of the advantageous features of a system of standards with the cost advantages of a fee system. The agency that administers the system determines the total number of permits and therefore the total amount of emissions, just as a system of standards would do. But the marketability of the permits allows pollution abatement to be achieved at minimum cost, just as a system of fees would do.[2]

EXAMPLE 18.1 THE COSTS AND BENEFITS OF REDUCED SULFUR DIOXIDE EMISSIONS

In 1968 Philadelphia imposed air quality regulations that limited the maximum allowable sulfur content in fuel oil to 1.0 percent or less. This regulation decreased sulfur dioxide levels in the air substantially-from 0.10 parts per million in 1968 to below0.025 parts per million in 1973. This improved air quality led to better human health, less damage to materials, and higher property values. But these improvements had a cost: Industrial, manufacturing, commercial, and residential fuel users had to alter their fuel choices and to install pollution-control equipment to abate the pollution. Was the benefit-the reduction in social cost due to the abatement-worth the additional abatement cost? A cost-benefit study of reductions in sulfur dioxide emissions provides some answers.[3]

In Philadelphia the emissions reductions necessitated increased costs of converting from coal and oil to gas to comply with the air quality regulation. Emissions control equipment also had to be added to manufacturing processes to ensure that fuels were used efficiently. Figure 18.7 shows the marginal social cost and the marginal cost to the firm of reduced emissions. Note that the marginal abatement cost jumps whenever new capital-intensive pollution control equipment is needed to improve fuel efficiency

The benefits of reduced sulfur dioxide emissions can he divided into three parts: (1) reductions in illness and death from diseases like cancer, bronchitis, pneumonia, emphysema, asthma, and the common cold; (2) reductions in materials costs caused by corrosion of metals, stone, and paint; and (3) improvements in visibility and other aesthetic values.

Because benefits are the negative of social costs, we can obtain information about the marginal social cost curve by asking how each of these three

[2] With limited information and costly monitoring, a marketable permit system is not always ideal. For example, if the total number of permits is chosen incorrectly and the marginal cost of abatement rises sharply for some firms, a permit system could drive those firms out of business by imposing high abatement costs. (This would also be a problem for fees.) For further discussion of fees, standards, and transferable pollution permits, see William J. Baumol and Wallace E. Oates, *Economics, Environmental Policy, and the Quality of Life* (Englewood Cliffs, N.J.: Prentice-Hall, 1979).

[3] The study is by Thomas R. Irvin, "A Cost-Benefit Analysis of Sulfur Dioxide Abatement Regulations in Philadelphia," *Business Economics* (Sept. 1977): 12-20.

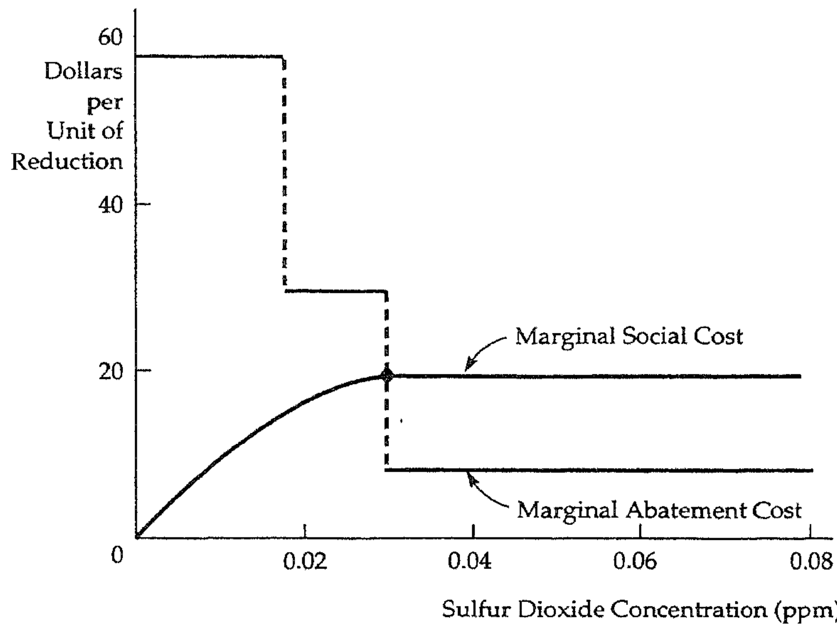

FIGURE 18.7 Sulfur Dioxide Emissions Reductions. The efficient sulfur dioxide concentration equates the marginal abatement cost to the marginal social cost. Here the marginal abatement cost curve is a series of steps, each representing the use of a different abatement technology.

types of benefits decreases in value when sulfur dioxide concentrations are increased. For very low concentrations, evidence suggests little health, material, or aesthetic effects. But for moderate concentrations of sulfur dioxide, studies of respiratory diseases, corrosion of materials, and lost visibility suggest that marginal social costs are positive and relatively constant. Thus, the marginal social cost curve is shown to rise initially and then become horizontal.

The efficient level of reduced sulfur dioxide emissions is given by the number of parts per million of sulfur dioxide at which the marginal cost of reduced emissions is equal to the marginal social cost. We can see from Figure 18.7 that this level is approximately 0.0275 parts per million. The marginal social cost and marginal abatement cost curves intersect at a point where the marginal abatement cost curve is sharply decreasing owing to the introduction of expensive desulfurization equipment. Because 0.0275 parts per million is slightly below the emissions level achieved in 1973 by the regulation, we can conclude that the regulation improved economic efficiency. In fact, given that sulfur dioxide levels were above 0.0275 parts per million for most of the period, it appears that the regulations were not stringent enough to achieve the most efficient outcome.

EXAMPLE 18.2 EMISSIONS TRADING AND CLEAN AIR

The cost of air pollution control during the 1980s was approximately $18 billion per year.[4] An effective emissions trading system could reduce those costs substantially in the decades to come. The Environmental Protection Agency's "bubble" and "offset" programs provided a modest attempt to use a trading system to lower cleanup costs. A bubble allows an individual firm to adjust its pollution controls for individual sources of pollutants, as long as a *total pollutant limit* for the firm is not exceeded.

In theory a bubble could be used to set pollutant limits for many firms or for an entire geographic region; in practice, however, it has been applied to individual firms. The result is, in effect, that "permits" are traded within the firm-if one part of the firm could reduce its emissions, another part of the firm would be allowed to emit more. Abatement cost savings associated with the EPA's program of 42 bubbles have been approximately $300 million since 1979.

Under the offset program, new sources of emissions may be located in regions in which air quality standards have not been met, but only if they offset their new emissions by reducing emissions from existing sources at least as much. Offsets can be obtained by internal trading, but external trading among firms is also allowed. Over 2,000 offset transactions have occurred since 1976.

Because of their limited natures, the bubble and offset programs substantially understate the potential gain from a broad-based emissions trading program. In one study, the cost of achieving an 85 percent reduction in hydrocarbon emissions in all of the DuPont plants in the United States was estimated under three alternative policies: (i) each source at each plant must reduce emissions by 85 percent; (ii) each plant must reduce its overall emissions by 85 percent; only internal trading is possible; and (iii) total emissions at all plants must be reduced by 85 percent, and both internal and external trading are possible.[5] When no trading was allowed, the cost of emissions reduction was $105.7 million. Internal trading reduced the cost to $42.6 million. Allowing for both external and internal trading reduced the cost further to $14.6 million.

Clearly, the potential cost savings from an effective transferable emissions program can be substantial. This may explain why Congress focused on transferable permits as a way of dealing with "acid rain" in the 1990 Clean Air Act. Acid rain is created when sulfur dioxide and nitrogen oxide pollution travels through the atmosphere and returns to earth as sulfuric and nitric acids. These acids can be extremely harmful to people, animals, vegetation, and buildings. The government has authorized a permit system to reduce sulfur dioxide emissions by 10 million tons and nitrogen oxide emissions by 2.5 million tons by the year 2000;

[4] See Robert W. Hahn and Gordon L. Hester, "The Market for Bads: EPA's Experience with Emissions Trading," *Regulation* (1987): 48-53.

[5] M.T Maloney and Bruce Yandle, "Bubbles and Efficiency: Cleaner Air at Lower Cost," *Regulation* (May/Iune 1980): 49-52.

Under the plan, each tradeable permit will allow a maximum of one ton of sulfur dioxide to be released into the air. Stations will be allocated permits in proportion to their current level of emissions. In the next decade the operability of the permit system will be tested; a major obstacle is the array of state public utility regulatory policies that could limit the ability of the market for permits to work.

Recycling

To the extent that the disposal of waste products involves no cost to either consumers or producers, society will dispose of too much waste material. The overutilization of virgin materials and the underutilization of recycled materials will result in a market failure that may require government intervention. Fortunately, given the appropriate incentive to recycle products, this market failure can be corrected.[6]

To see how recycling incentives can work, consider a typical household's decision with respect to the disposal of glass containers. In many communities, households are charged a fixed annual fee for trash disposal. As a result, these households can dispose of glass and other garbage at very low cost-only the time and effort to put the materials in a trash receptacle.

The low cost of disposal creates a divergence between the private and the social cost of disposal. The marginal private cost of disposal, which is the cost to the household of throwing out the glass, is likely to be constant (independent of the amount of disposal) for low to moderate levels of disposal, and then to increase for large disposal levels involving additional shipping and dump charges. In contrast, the social cost of disposal includes the harm to the environment from littering as well as the injuries caused by sharp glass objects. Marginal social cost is likely to increase, in part because the marginal private cost is increasing, and in part because the environmental and aesthetic costs of littering are likely to increase sharply as the level of disposal increases.

Both cost curves are shown in Figure 18.8. In the figure, the horizontal axis measures, from left to right, the amount of scrap material m that the household disposes, up to a maximum of 12 pounds per week. Consequently, the amount recycled can be read from right to left. As the amount of scrap disposal increases, the marginal private cost, MC, increases, but at a much lower rate than the marginal social cost MSC.

Recycling of containers can be accomplished by a municipality or a private firm that arranges for collection, consolidation, and processing of materials. The marginal cost of recycling is likely to increase as the amount of recycling

[6] Even without market intervention, some recycling will occur if the price of virgin material is sufficiently high. For example, recall from Chapter 2 that when the price of copper is high, there is more recycling of scrap copper.

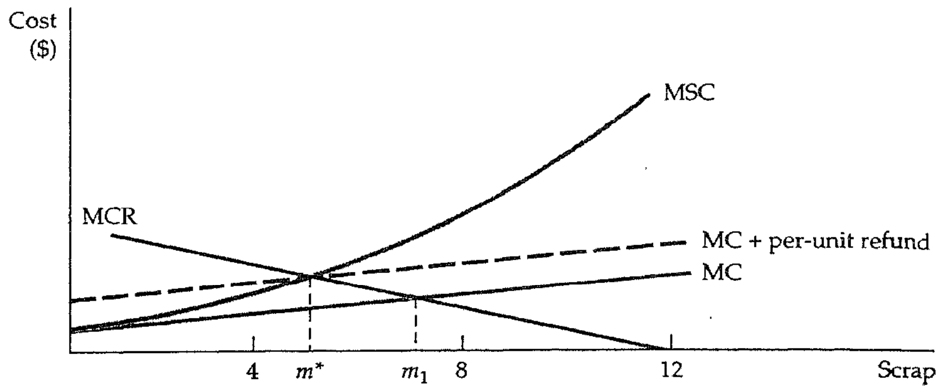

FIGURE 18.8 The Efficient Amount of Recycling. The efficient amount of recycling of scrap material is the amount that equates the marginal social cost of scrap disposal, MSC, to the marginal cost of recycling, MCR. The efficient amount of scrap for disposal m^* is less than the amount that will arise in a private market, m_1.

grows, in part because collection, separation, and cleaning costs grow at an increasing rate. The marginal cost of recycling curve, MCR, in Figure 18.8 is best read from right to left Thus, when there is 12 pounds of disposed material, there is no recycling and the marginal cost is zero. As the amount of disposal decreases, the amount of recycling increases, and the marginal cost of recycling increases.

The efficient amount of recycling occurs at the point at which the marginal cost of recycling, MCR, is equal to the marginal *social* cost of disposal, MSC. As Figure 18.8 shows, the efficient amount of scrap for disposal m^* is less than the amount that will arise in a private market, m_1.

Why not utilize a disposal fee, a disposal standard, or even transferable disposal permits to resolve this externality? Any of these policies can help in theory, but they are not easy to put into practice, and are rarely used. For example, a disposal fee is difficult to implement because it would be very costly for a community to sort through trash to separate and then to collect glass materials. Pricing and billing for the scrap disposal would also be expensive, since the weight and composition of materials would affect the social cost of the scrap and, therefore, the appropriate price to be charged.

One policy solution that has been used with some success to encourage recycling is the *refundable deposit*[7] Under a refundable deposit system an initial deposit is paid to the store owner when the glass container product is purchased. The deposit is refunded if and when the container is returned to the

[7] See Tom Tietenberg, *Environmental and Natural Resource Economics* (Chicago: Scott, Foresman, and Company, 1988), Chapter 8 for a general discussion of recycling, and Richard Porter, "A Social Benefit-Cost Analysis of Mandatory Deposits on Beverage Containers,"*Journal of Environmental Economics and Management* (1978): 351-366, for an analysis of mandatory deposit systems.

store or to a recycling center. Refundable deposits create a desirable incentive: the per-unit refund can be chosen so that households (or firms) recycle more material.

From an individual's point of view, the refundable deposit creates an additional private cost of disposal-the opportunity cost of failing to obtain a refund. As shown in Figure 18.8, with the higher cost of disposal, the individual will reduce disposal and increase recycling to the optimal social level m^*.

A similar analysis applies at the industry level. Figure 18.9 shows a downward sloping market demand for glass containers, D. The supply of virgin glass containers is given by S_v and the supply of recycled glass by S_r. The market supply S is the horizontal sum of these two curves. As a result, the market price of glass is P, and the equilibrium supply of recycled glass is M_1.

By raising the relative cost of disposal and encouraging recycling, the refundable deposit increases the supply of recycled glass from S, to S'_r, the aggregate supply increases from S to S', and the price of glass falls to P'. As a result, the quantity of recycled glass increases to M^*, which means a decrease in the amount of disposed glass.

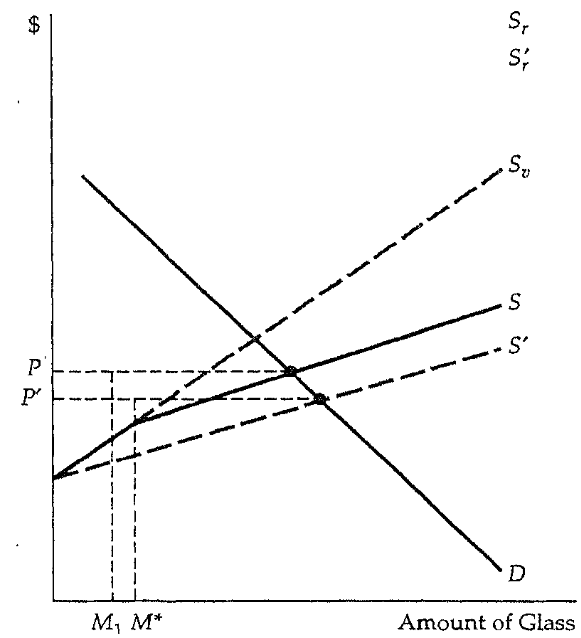

FIGURE 18.9 Refundable Deposits. Initially equilibrium in the market for glass containers involves a price P and a supply of recycled glass M_1. By raising the relative cost of disposal and encouraging recycling, the refundable deposit increases the supply of recycled glass from S_r to S'_r and the aggregate supply of glass from S to S'. The price of glass then falls to P', the quantity of recycled glass increases to M^*, and the amount of disposed glass decreases.

The refundable deposit scheme has another advantage-a market for recycled products is created. In many communities public or private firms as well as private individuals specialize in collecting and returning recyclable materials As this market becomes larger and more efficient, the demand for recycled rather than virgin materials increases, therefore increasing the benefit to the environment.

EXAMPLE 18.3 REGULATING MUNICIPAL SOLID WASTES

By 1990 the average resident of Los Angeles was generating about 6.4 pounds of solid waste per day, and residents of other large American cities were not far behind. By contrast, residents of Tokyo, Paris, Hong Kong, and Rome generated 3 pounds, 2.4 pounds, 1.9 pounds, and 1.5 pounds, respectively.[8] Some of these differences are due to variations in consumption levels, but most of the differences are due to the efforts that many other countries have made to encourage recycling. In the United States, only about 25% of aluminum, 23% of paper, and 8.5% of glass scrap are recycled.

A number of policy proposals have been introduced to encourage recycling in the United States. The first is the refundable deposit described above. A second policy is a *curbside charge,* in which communities charge individuals a fee for refuse disposal that is proportional to the weight (or the volume) of the refuse. To encourage separation of recyclable materials, all separable glass materials are collected for free. Curbside charges encourage recycling, but they fail to discourage consumption of products that might require recycling.

A third alternative is to require the *mandatory separation* of recyclable materials such as glass. Random spot checks with substantial penalties for violations are required to make the system effective. Mandatory separation is perhaps the least desirable of the three alternatives, not only because it is difficult to implement, but also because individuals, if the cost of separation is sufficiently high, may be encouraged to shift to alternative containers such as plastic, which are environmentally damaging and which cannot readily be recycled.

The potential effectiveness of these three policies is illustrated by a recent analysis that focused on the mix between glass and plastic. Consumers were' assumed to have varying preferences, with half preferring glass and half preferring plastic, for products that are otherwise identical in price, quantity, and quality. Without any incentive to recycle,a 50-50% division between glass and plastic would result. From a social perspective, however, greater use of recyclable glass would be preferred.

Mandatory separation fails as a policy in this case-the cost of separation is so high that the percentage of glass container materials purchased actually falls to 40%. A curbside charge does much better-it leads to a 72.5% use of recyclable glass. Finally, a refundable deposit system does best, with 78.9% of consumers purchasing recyclable glass containers.

[8] This example is based on Peter S. Menell, "Beyond the Throwaway Society: An Incentive Approach to Regulating Municipal Solid Waste," *Ecology Law Quarterly* (1990): 655-739.

A recent case in Perkasie, Pennsylvania shows that recycling programs can indeed be effective. Prior to implementation of a program combining all three of the economic incentives just described, the total amount of unseparated solid waste was 2573 tons per year. When the program was implemented this amount fell to within 1038 tons, a 59% reduction. As a result, the town saved $90,000 per year in disposal costs.

183 *Externalities and Property Rights*

We have seen how government regulation can deal with the inefficiencies that arise from externalities. Emissions fees and transferable emissions permits work because they change a firm's incentives-forcing it to take into account the external costs that it imposes. But government regulation is not the only way to deal with externalities. In this section we show that in some circumstances inefficiencies can be eliminated through private bargaining among the affected parties, or by a legal system in which parties can sue to recover the damages they suffer.

Property Rights

Property rights are the legal rules that describe what people or firms may do with their property. When people have property rights to land, for example, they may build on it or sell it and are protected from interference by others.

To see why property rights are important, let's return to our example of the firm that dumps effluent into the river. We assumed that it had a property right to use the river to dispose of its waste, and that the fishermen did not have a property right to "effluent-free" water. As a result, the firm had no incentive to include the cost of effluent in its production calculations. In other words, the firm externalized the costs generated by the effluent. Suppose the fishermen owned the river, i.e., had a property right to clean water. Then they could demand that the firm pay them for the right to dump effluent. The firm would either cease production or pay the costs associated with the effluent. These costs would be internalized, and an efficient allocation of resources could be achieved.

Bargaining and Economic Efficiency

Economic efficiency can be achieved without government intervention when the externality affects relatively few parties and when property rights are well specified. To see how this might arise, let's consider a numerical version of the

TABLE 18.1 Profits Under Alternative Emissions Choices (Daily)

	Factory Profit	Fishermen's Profit	Total Profit
No filter, no treatment plant	$500	$100	$600
Filter, no treatment plant	$300	$500	$800
No filter, treatment plant	$500	$200	$700
Filter, treatment plant	$300	$300	$600

effluent example. Suppose the steel factory's effluent reduces the fishermen's profit. As Table 18.1 shows, the factory can install a filter system to reduce its effluent, or the fishermen can pay for the installation of a water treatment plant.[9]

The efficient solution maximizes the joint profit of the factory and the fishermen. This occurs when the factory installs a filter and the fishermen do not build a treatment plant. Let's see how alternative property rights lead these two parties to negotiate different solutions.

Suppose the factory has the property right to dump effluent into the river. Initially, the fishermen's profit is $100, and the factory's is $500. By installing a treatment plant, the fishermen can increase their profit to $200, so that the joint profit without cooperation is $700 ($500 + $200). Moreover, the fishermen are willing to pay the factory up to $300 to install a filter ($300 is the difference between the $500 profit with a filter and the $200 profit without cooperation). Because the factory loses only $200 in profit by installing a filter, it will be willing to do so if it is more than compensated for its loss. The gain to both parties by cooperating is equal to $100 in this case (the $300 gain to the fishermen less the $200 cost of a filter).

Suppose the factory and the fishermen agree to plit this gain equally by having the fishermen pay the factory $250 to install the filter. As Table 18.2

TABLE 18.2 Bargaining With Alternative Property Rights

	Right to Dump	Right to Clean Water
No *cooperation*		
Profit of factory	$500	$300
Profit of fishermen	$200	$500
Cooperation		
Profit of factory	$550	$300
Profit of fishermen	$250	$500

[9] For a more extensive discussion of a variant of this example see Robert Cooter and Thomas Ulen, *Law and Economics* (Glenview, IL: Scott-Foresman, 1987), Chapter 4.

shows, this bargaining solution achieves the efficient outcome. Under the column "Right to Dump," we see that without cooperation the fishermen earn a profit of $200 and the factory $500. With cooperation, the profit of both increases by $50.

Now suppose the fishermen are given the property right,to clean water, which requires the factory to install the filter. The factory earns a profit of $300 and the fishermen $500. Because neither party can be made better off by bargaining, the initial outcome is efficient.

This analysis applies to all situations in which property rights are well specified. *When parties can bargain without cost and to their mutual advantage, the resulting outcome will be efficient, regardless of how the property rights are specified.* The italicized proposition is called the *Coase Theorem,* in honor of Ronald Coase, who did much to develop it.[10]

Costly Bargaining-The Role of Strategic Behavior

Bargaining can be time consuming and costly, especially when property rights are not clearly specified. Then neither party is sure how hard to bargain before the other party will agree to a settlement. In our example, both parties knew that the bargaining process had to settle on a payment between $200 and $300. If the parties were unsure of the property rights, however, the fishermen might be willing to pay only $100, and the bargaining process would break down.

Bargaining can also break down even when communication and monitoring are costless, if both parties believe they can obtain larger gains. One party makes a demand for a large share and refuses to bargain, assuming incorrectly that the other party will eventually concede. This *strategic behavior* can lead to an inefficient, noncooperative outcome. Suppose the factory has the right to emit effluent and claims that it will not install a filter unless it receives $300, and its offer is final. The fishermen offer to pay at most $250, however, believing that eventually the factory will agree to the "fair" solution. In this situation, an agreement may never be reached, especially if one or both parties want to earn a reputation for tough bargaining.

A Legal Solution-Suing for Damages

In many situations involving externalities, a party that is harmed (the victim) by another has the legal right to sue. If successful, the victim can recover monetary damages equal to the harm it has been caused. A suit for damages is different from an emissions or effluent fee because the victim, not the government, is paid.

To see how the potential for a lawsuit can lead to an efficient outcome, let's reexamine our fishermen-factory example. Suppose first that the fishermen

[10] See Ronald Coase, "The Problem of Social Cost," *Journal of Law and Economics* 3 (1960): 1-44.

are given the right to clean water (meaning that the factory is responsible for harm to the fishermen *if the* factory does not install a filter). The harm to the fishermen in this case is $400 (the difference between the profit that the fishermen make when there is no effluent [$500] and their profit when there is effluent [$100]). The factory has the following options:

1. Do not install filter, pay damages:	Profit = $100 ($500 - $400)
2. Install filter, avoid damages:	Profit = $300 ($500 - $200)

The factory will find it advantageous to install a filter, which is substantially cheaper than paying damages, and the efficient outcome will be achieved.

An efficient outcome (with a different division of profits) will also be achieved if the factory is given the property right to emit effluent. Under the law, the fishermen would have the legal right to require the factory to install the filter, but they would have to pay the factory for its $200 lost profit (not for the cost of the filter). This leaves the fishermen three options:

1. Put in a treatment plant:	Profit = $200
2. Have factory put in a filter, but pay damages:	Profit = $300 ($500 - $200)
3. Do not put in treatment plant or require a filter:	Profit = $100

The fishermen earn the highest profit if they take the second option; they will require the factory to put in a filter but compensate the factory $200 for its lost profit. Just as in the situation in which the fishermen had the right to clean water, this outcome is efficient because the filter has been installed. Note, however, that the $300 profit is substantially less than the $500 profit that the fishermen get when they have a right to clean water.

This example shows that a suit for damages eliminates the need for bargaining because it specifies the consequences of the choices that the parties have to make. Giving the party that is harmed the right to recover damages from the injuring party ensures an efficient outcome.[11]

EXAMPLE 18.4 THE COASE THEOREM AT WORK

The Coase Theorem applies to governments as well as to people, as a September 1987 cooperative agreement between New York City and New Jersey illustrates.

For many years garbage spilling from waterfront trash facilities from New York harbor had adversely affected the quality of water along the New Jersey shore and occasionally littered the beaches. One of the worst instances occurred

[11] When information is imperfect, however, suing for damages may lead to inefficient outcomes,

on August 13-15,1987, when more than 200 tons of garbage, including syringes and crack-cocaine vials, formed a 50-mile-long slick off the New Jersey shore.

In this situation New Jersey has the right to clean beaches, and can sue New York City to recover damages associated with garbage spills. New Jersey can also ask the court to grant an injunction that would require New York City to stop using its trash facilities until the problem is removed.

But New Jersey wanted cleaner beaches, not simply the recovery of damages. And New York wanted to be able to operate its trash facility As a result, there was room for mutually beneficial exchange. After two weeks of negotiations, New York and New Jersey reached a settlement. New Jersey agreed not to bring a lawsuit against the city. New York City agreed to use special boats and other floatation devices to contain spills that might arise from Staten Island and Brooklyn. It also agreed to create a monitoring team to survey all trash facilities and shut down those that failed to comply. At the same time, New Jersey officials were allowed unlimited access to New York City's trash facilities to monitor the effectiveness of the program.

18.4 *Common Property Resources*

Occasionally externalities arise when resources can be used without payment. *Common property resources* are those to which anyone has free access. As a result, they are likely to be overutilized. Air and water are the two most common examples of these resources. Other examples include fish, animal populations, mineral exploration, and extraction. Let's look at some of the inefficiencies that can occur when resources are common property rather than privately owned.

Consider a large lake with trout, to which an unlimited number of fishermen have access. Each fisherman fishes up to the point at which the marginal revenue from fishing (or the marginal value, if fishing is for sport instead of profit) is equal to the cost. But the lake is a common property resource, and no fisherman has the incentive to take into account how his fishing affects the opportunities of others. As a result, the fisherman's private cost understates the true cost to society because more fishing reduces the stock of fish, making less available for others.[12] This leads to an inefficiency-too many fish are caught.

Figure 18.10 illustrates this. Suppose that the fish catch is sufficiently small relative to demand, so that fishermen take the price of fish as given. Suppose also that someone can control the number of fishermen that have access to

[12] We made a similar argument in our discussion of depletable resources in Section 15.7.

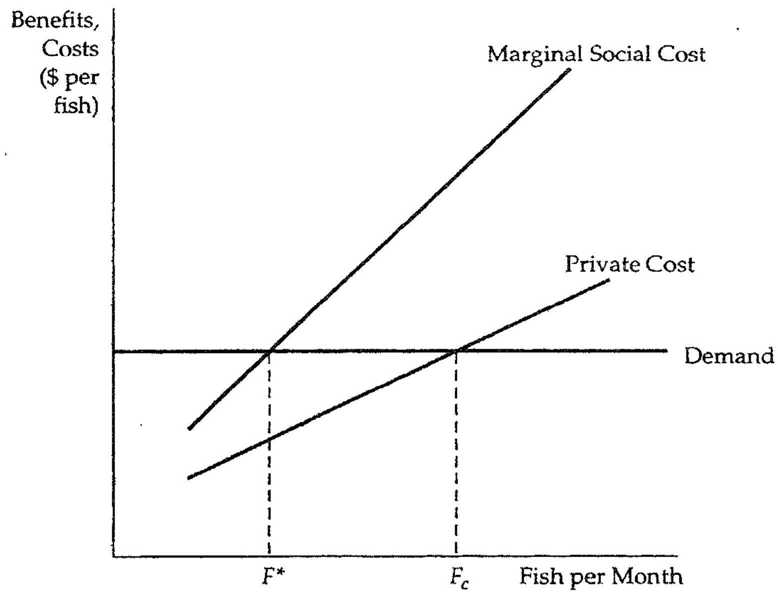

FIGURE 18.10 Common Property Resources. When a common property resource, such as a fishery, is accessible to all, the resource is used up to the point *Fc* at which the private cost is equal to the additional revenue generated. This usage exceeds the efficient level *F** at which the marginal social cost of using the resource is equal to the marginal benefit (as given by the demand curve).

the lake. The efficient level of fish per month *F** is determined at the point at which the marginal benefit from fish caught is equal to the marginal sodal cost. The marginal benefit is the price taken from the demand curve. The marginal sodal cost is shown in the diagram to include not only the private operating costs but also the sodal cost of depleting the stock of fish.

Now compare the efficient outcome with what happens when the lake is common property. Then, the marginal external costs are not taken into account, and each fisherman fishes until there is no longer any profit to be made. When only *F** fish are caught, the revenue from fishing is greater than the cost, and there is a profit to be earned by fishing more. Entry into the fishing business occurs until the point at which the price is equal to the marginal cost, point Fc in our diagram. But, at *Fc,* too many fish will be caught.

There is a relatively simple solution to the common property resource problem-let a single owner manage the resource. The owner will set a fee for use of the resource that is equal to the marginal cost of depleting the stock of fish'. Facing the payment of this fee, fishermen in the aggregate will no longer find it profitable to catch more than *F** fish. Unfortunately, most common property resources are vast, and single ownership may not be practical. Then, government ownership or direct government regulation may be needed.

EXAMPLE 18.5 CRAWFISH FISHING IN LOUISIANA

In recent years, crawfish has become a popular restaurant item. In 1950, for example, the annual crawfish harvest in the Atchafalaya river basin in Louisiana was just over 1 million pounds. By 1990 it had grown to nearly 30 million pounds. Because most crawfish grow in ponds to which fishermen have unlimited access, a common property resource problem has arisen-too many crawfish have been trapped, causing the crawfish population to fall far below the efficient level.

How serious is the problem? Specifically, what is the social cost of unlimited access to fishermen? The answer can be found by estimating the private cost of trapping crawfish, the marginal social cost, and the demand for crawfish. Figure 18.11 shows portions of the relevant curves.[13] Private cost is upward-sloping because as the catch increases, so does the additional effort that must

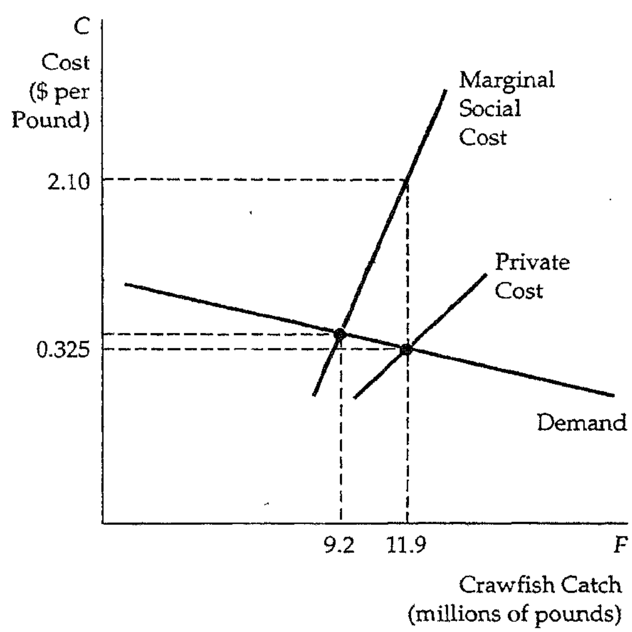

FIGURE 18.11 Crawfish as a Common Property Resource. Because crawfish are reared in ponds to which fishermen have unlimited access, they are a common property resource. The efficient level of fishing occurs when the marginal benefit is equal to the marginal social cost. However, the actual level of fishing occurs at the point at which the price for crawfish is equal to the private cost of fishing. The tan-shaded area represents the social cost of the common property resource.

[13] This example was based on Frederick W Bell, "Mitigating the Tragedy of the Commons," *Southern Economic Journal* 52 (1986): 653-664.

be made to obtain it.The demand curve is downward sloping but elastic because other shellfish are close substitutes for crawfish.

We can find the efficient crawfish catch graphically or algebraically. To do so, let F represent the catch of crawfish in millions of pounds per year (shown on the horizontal axis), and let C represent cost in dollars per pound (shown on the vertical axis). In the region where the various curves intersect, the three curves in the graph are as follows:

Demand:	$C = 0.401 - 0.0064F$
Marginal Social Cost:	$C = -5.645 + 0.6509F$
Private Cost:	$C = -0.357 + 0{,}0573F$

The efficient crawfish catch of 9.2 million pounds, which equates demand to marginal social cost, is shown as the intersection of the two curves. The actual catch, 11.9 million pounds, is determined by equating demand to private cost and is shown as the intersection of those two curves. The shaded area in the figure measures- the social cost of free access. This represents the excess of social cost above the private benefit of fishing summed from the efficient level (where demand is equal to marginal social cost) to the actual level (where demand is equal to private cost). In this case, the social cost is approximated by the area of a triangle with a base of 2.7 million pounds (11.9 - 9.2), and a height of $1.775 ($2.10 – $0.325), or $2,396,000. Note that by regulating the ponds-limiting access or limiting the size of the catch-this social cost could be avoided.

[redacted]

18.5 *Public Goods*

We have seen that externalities, including common property resources, create market inefficiencies that sometimes warrant government regulation. When, if ever, should governments replace private firms as the producer of goods and services? In this section we describe a set of conditions under which the private market either may not provide a good at all or may not price it properly once it is available.

Public goods have two characteristics: They are *nonrival* and *nonexclusive.* A good is *nonrival* if for any given level of production, the marginal cost of providing it to an additional consumer is zero. For most goods that are provided privately, the marginal cost of producing more of the good is positive. But for some goods, additional consumers do not add to cost. Consider the use of a highway during a periodof low traffic volume. Because the highway already exists and there is no congestion, the additional cost of driving on it is zero. Or consider the use of a lighthouse by a ship. Once the lighthouse is built and functioning, its use by an additional ship adds nothing to its running costs. Finally, consider public television. Clearly, the cost of one more viewer is zero.

Most goods are rival in consumption. For example, when you buy furniture, you have ruled out the possibility that someone else can buy it. Goods that are rival must be allocated among individuals. Goods that are nonrival can be made available to everyone without affecting any individual's opportunity for consuming them.

A good is *nonexclusive* if people cannot be excluded from consuming it. As a consequence, it is difficult or impossible to charge people for using nonexclusive goods-the goods can be enjoyed without direct payment. One example of a nonexclusive good is national defense. Once a nation has provided for its national defense, all citizens enjoy its benefits. A lighthouse and public television are also examples of nonexclusive goods.

Nonexclusive goods need not be national in character. If a state or city eradicates an agricultural pest, all farmers and consumers benefit. It would be virtually impossible to exclude a particular farmer from the benefits of the program. Automobiles are exclusive (as well as rival). If a dealer sells a new car to one consumer, then the dealer has excluded other individuals from buying the car.

Some goods are exclusive but nonrival. For example, in periods of low traffic, travel on a bridge is nonrival because an additional car on the bridge does not lower the speed of other cars. But bridge travel is exclusive because bridge authorities can keep people from using it. A television signal is another example. Once a signal is broadcast, the marginal cost of making the broadcast available to another user is zero, so the good is nonrival. But broadcast signals can be made exclusive by scrambling the signal and charging for the code that allows it to be unscrambled.

Some goods are nonexclusive but rival. Air is nonexclusive but can be rival if the emissions of one firm adversely affect the quality of the air and the ability of others to enjoy it. An ocean or large lake is nonexclusive, but fishing is rival because it imposes costs on others—the more fish caught, the fewer fish available to others.

Public goods, which are both nonrival and nonexclusive, provide benefits to people at zero marginal cost, and no one can be excluded from enjoying them. The classic example of a public good is national defense. Defense is nonexclusive, as we have seen, but it is also nonrival because the marginal cost of providing defense to 'an additional person is zero. The lighthouse mentioned earlier is also a public good, because it is nonrival and nonexclusive, i.e., it would be difficult to charge ships for the benefits they receive from it.[14]

The list of public goods is much smaller than the list of goods that governments provide. Many publicly provided goods are either rival in consumption, exclusive, or both. For example, high school education is rival in con-

[14] Lighthouses need not be provided by the government. See Ronald Coase, "The Lighthouse in Economics," *Journal of Law and Economics* 17 (1974): *357-376,* for a description of how lighthouses were privately provided in nineteenth-century England.

sumption. There is a positive marginal cost of providing education to one more child because other children get less attention as class sizes increase. Likewise, charging tuition can exclude some children from enjoying education. Public education is provided by local government because it entails positive externalities, not because it is a public good.

Finally, consider the management of a national park. Part of the public can be excluded from using the park by raising entrance and camping fees. Use of the park is also rival-because of crowded conditions, the entrance of an additional car into a park can reduce the benefits that others receive from it.

Efficiency and Public Goods

The efficient level of provision of a private good is determined by comparing the marginal benefit of an additional unit to the marginal cost of producing the unit. Efficiency is achieved when the marginal benefit and the marginal cost are equal. The same principle applies to public goods, but the analysis is different. With private goods, the marginal benefit is measured by the benefit the consumer receives. With a public good, we must ask how much each person values an additional unit of output. The marginal benefit is obtained by adding these values for all people who enjoy the good. Then to determine the efficient level of provision of a public good, we must equate the sum of these marginal benefits to the marginal cost of production.

Figure 18.12 illustrates the efficient level of producing a public good. D_1 represents the demand for the public good by one consumer, and D_2 the demand by a second consumer. Each demand curve tells us the marginal benefit that the consumer gets from consuming every level of output. For example, when there are 2 units of the public good, the first consumer is willing to pay $1.50 for the good, and $1.50 is the marginal benefit. Similarly, the second consumer has a marginal benefit of $4.00.

To calculate the sum of the margmal benefits to both people, we must add each of the demand curves *vertically*. For example, when the output is 2 units, we add the marginal benefit of $1.50 to the marginal benefit of $4.00 to obtain a marginal social benefit of $5.50. When this is calculated for every level of public output, we obtain the aggregate demand curve for the public good *D*.

The efficient amount of output is the one at which the marginal benefit to society is equal to the margmal cost. This occurs at the intersection of the demand and the marginal cost curves. In our example, the marginal cost of production is $5.50, so 2 is the efficient output level.

To see why 2 is efficient, note what happens if only 1 unit of output is provided: The marginal cost remains at $5.50, but the marginal benefit is approximately $7.00. Because the marginal benefit is greater than the marginal cost, too little of the good has been provided. Similarly, suppose 3 units of the public good have been produced. Now the marginal benefit of approximately $4.00 is less than the marginal cost of $5.50, and too much of the good has

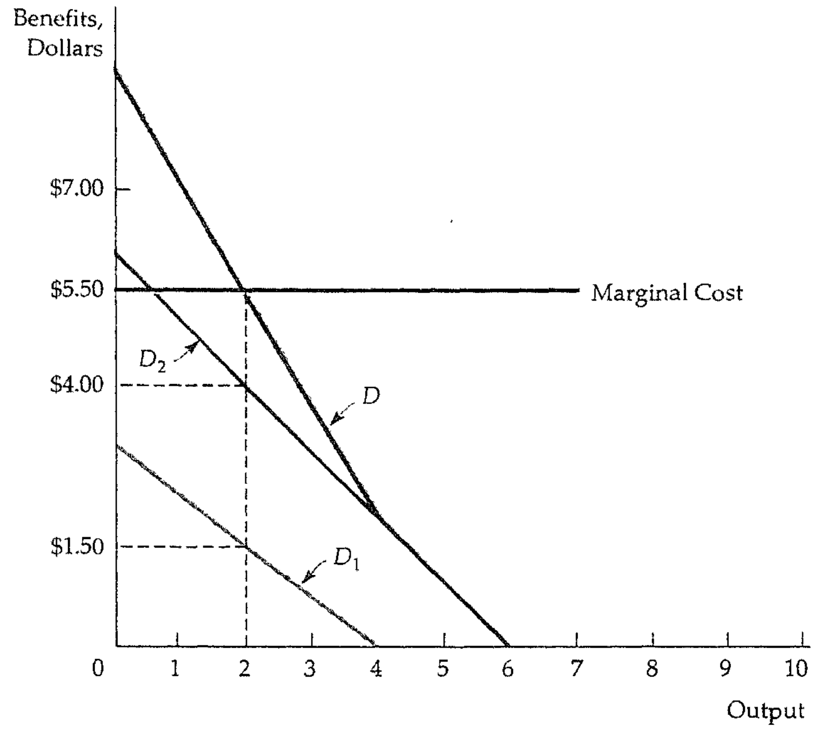

FIGURE 18.12 Efficient Public Good Provision. When a good is nonrival, the social marginal benefit of consumption, given by the demand curve *D*, is determined by vertically summing the individual demand curves for the good, D_1 and D_2. At the efficient output, the demand and the marginal cost curves intersect.

been provided. Only when the marginal social benefit is equal to the marginal cost is the public good provided efficiently. [15]

Public Goods and Market Failure

Suppose you are considering providing a mosquito abatement program for your community. You know that the program is worth more to the community than the $50,000 it will cost. Can you make a profit by providing the program privately? You would break even if you assessed a $5.00 fee to each of the 10,000 households in your community. But you cannot force them to pay the fee, let alone devise a system in which those households that value mosquito abatement the most pay the highest fees.

[15] We have shown that nonexclusive, nonrival goods are inefficiently provided. A similar argument would apply to nonrival but exclusive goods.

The problem is that mosquito abatement is nonexclusive-there is no way to provide the service without benefiting everyone. As a result, households do not have the incentive to pay what the program really is worth to them. People can act *as free riders*, understating the value of the program so that they can enjoy its benefit without paying for it.

With public goods, the presence of free riders makes it difficult or impossible for markets to provide goods efficiently. Perhaps if few people were involved and the program were relatively inexpensive, all households might agree voluntarily to share its costs. However, when many households are involved, voluntary private arrangements are usually ineffective, and the public good must be subsidized or provided by governments if it is to be produced efficiently.

EXAMPLE 18.6 THE DEMAND FOR CLEAN AIR

In Example 4.5 we used the demand curve for clean air to calculate the benefits of a cleaner environment. Now let's examine the public good characteristics of clean air. Many factors, including the weather, driving patterns, and industrial emissions determine air quality in a region. Any effort to clean up the air will generally improve air quality throughout the region. As a result, clean air is nonexclusive-it is difficult to stop any one person from enjoying it. Clean air is also nonrival-my enjoyment does not inhibit yours.

Because clean air is a public good, there is no market and no observable prices .at which people are willing to trade clean air for other commodities. Fortunately, we can infer people's willingness to pay for clean air from the housing market-households will pay more for a home located in an area with good air quality than for an otherwise identical home in an area with poor air quality.

Let's look at the estimates of the demand for clean air obtained from a statistical analysis of housing data for the Boston metropolitan area.[16] The statistical analysis correlates housing prices with the quality of air and other characteristics of the houses and their neighborhoods. Figure 18.13 shows three demand curves in which the value put on clean air depends on the level of nitrogen oxides and on income. The horizontal axis measures the level of air pollution in terms of parts per hundred million (pphm) of nitrogen oxides in the air,and the vertical axis measures each household's willingness to pay for a one-part-per-hundred million reduction in the nitrogen oxide level.

The demand curves are upward sloping because we are measuring pollution rather than clean air on the horizontal axis. As we would expect, the cleaner the air, the lower the willingness to pay for more of the good. These differences in the willingness to pay for clean air vary substantially. In Boston, for example, nitrogen oxide levels ranged from. 3 to 9 pphm. A middle-income

[16] See David Harrison, Jr., and Daniel L. Rubinfeld, "Hedonic Housing Prices and the Demand for Clean Air," *Journal of Environmental Economics and Management* 5 (1978): 81-102.

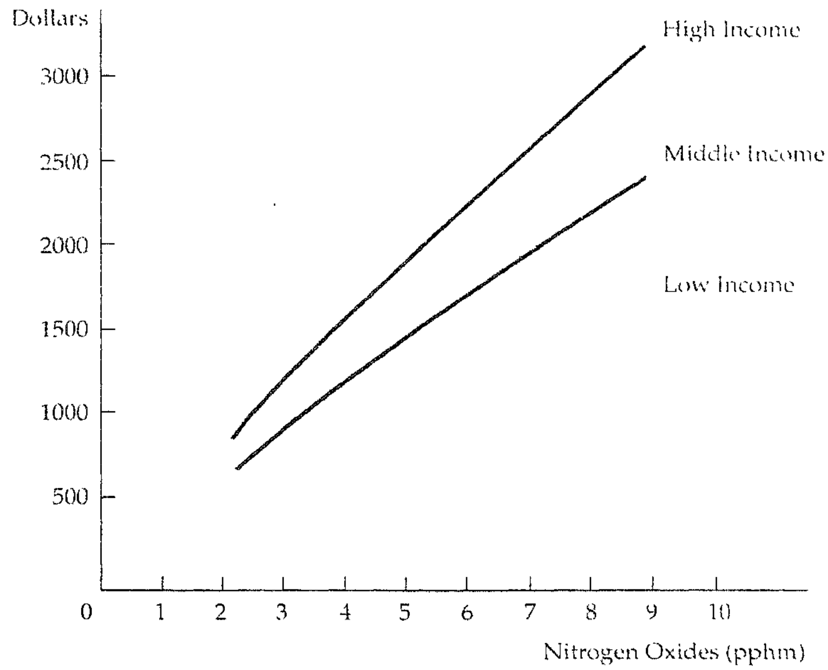

FIGURE 18.13 The Demand for Clean Air. The three curves describe the willingness to pay for clean air (a reduction in the level of nitrogen oxides) for each of three different households (low income, middle income, and high income). In general, higher-income households have greater demands for clean air than lower-income households. Also, each household is less willing to pay for clean air as the level of air quality increases.

household would be willing to pay $800 for a 1 pphm reduction in nitrogen oxide levels when the level is 3 pphm, but the figure would jump to $2200 for a 1 pphm reduction when the level is 9 pphm.

Note that higher-income households are willing to pay more to obtain a small improvement in air quality than lower-income households. At low nitrogen oxide levels (3 pphm), the differential between low- and middle-income households is only-$200, but at high levels (9 pphm), the differential increases to about$700.

With the quantitative information about the demand for clean air and separate estimates of the costs of improving air quality, we can determine whether the benefits of environmental regulations outweigh the costs. A study by the National Academy of Sciences of the regulations on automobile emissions did just this. *The* study found that automobile emissions controls would lower the level of pollutants, such as nitrogen oxides, by approximately 10 percent. The benefit to all residents of the United States of this 10 percent improvement in air quality was calculated to be approximately $2 billion. The study also estimated that it would cost somewhat less than $2 billion to install pollution control equipment in automobiles to meet the automobile emissions standards. The study concluded, therefore, that the benefits of the regulations did outweigh the costs.[17]

18.6 *Private Preferences for Public Goods*

Government production of a public good is advantageous because the government can assess taxes or fees to pay for it. But how can government determine how much of a public good to provide when the free rider problem gives people the incentive to misrepresent their preferences? In this section we discuss one mechanism for determining private preferences for goods that the government produces.

Voting is commonly used to decide allocation questions. For example, people vote directly on some local budget issues and elect legislators who vote on others. Many state and local referenda are based on *majority rule voting:* Each person has one vote, and the .candidate or the issue that receives more than 50 percent of the votes wins. Let's see how majority rule voting determines the provision of public education. Figure 18.14 describes the preferences for spending on education (on a per-pupil basis) of three citizens who are representative of three interest groups in the school district.

Curve W_1 gives the first citizen's willingness to pay for education, net of any required tax payments. The willingness to pay for each spending level is the maximum amount of money the citizen will pay to enjoy that spending level rather than no spending at all.[18] In general, the benefit from increased spending on education increases as spending increases. But the tax payments required to pay for that education increase as well. The willingness-to-pay curve, which represents the net benefit of educational spending, initially slopes upward because the citizen places great value on low spending levels. When spending increases beyond $600 per pupil, however, the value that the household puts on education increases at a diminishing rate, so the net benefit actually declines. Eventually, the spending level becomes so great (at $2400 per pupil) that the citizen is indifferent between this level of spending and no spending at all.

Curve W_2, which represents the second citizen's willingness to pay (net of taxes) is similarly shaped but reaches its maximum at a spending level of $1200 per pupil. Finally, W_3, the willingness to pay of the third citizen, peaks at $1800 per pupil.

[17] See U.S. Senate, Committee on Public Works, *Air Quality and Automobile Emission Control,* Vol. 4 (Washington, D.C: U.S. Government Printing Office, Sept. 1974).

[18] In other words, the willingness to pay measures the consumer surplus that the citizen enjoys when a particular level of spending is chosen.

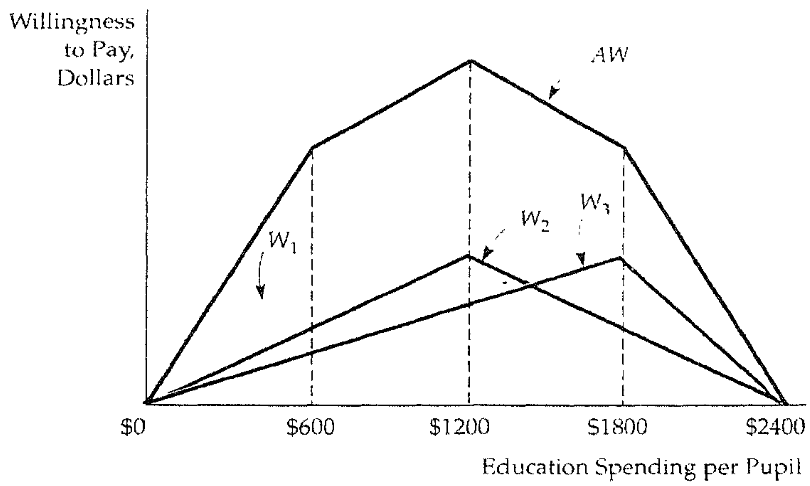

FIGURE 18.14 Determining the Level of Educational Spending. The efficient level of educational spending is determined by summing the willingness to pay for education (net of tax payments) of each of three citizens. Curves W_1 W_2, and W_3 represent their willingness to pay, and curve AW represents the aggregate willingness to pay. The efficient level of spending is $1200 per pupil. The level of spending actually provided is the level demanded by the median voter. In this particular case, the median voter's preference (given by the peak of the W_2 curve) is also the efficient level.

The solid line labeled AW represents the aggregate willingness to pay for education-the vertical summation of the W_1 W_2, and W_3 curves. The AW curve provides a measure of the maximum amount that all three citizens are willing to pay to enjoy each spending level. As Figure 18.14 shows, the aggregate willingness to pay is maximized when $1200 per pupil is spent. Because the AW curve measures the benefit of spending net of the tax payments required to pay for that spending,the maximum point, $1200 per pupil, also represents the efficient level of spending.

Will majority rule voting achieve the efficient outcome in this case? Suppose the public must vote whether to spend $1200 or $600 per pupil. The first citizen will vote for $600, but the other two citizens will vote for $1200, which will then have been chosen by majority rule. In fact, $1200 per pupil will beat any other alternative in a majority rule vote. Thus, $1200 represents the most preferred alternative of the *median voter*-the citizen with the median or middle preference. (The first citizen prefers $600 and the third $1800.) *Under majority rule voting, the preferred spending level of the median voter will always win an election against any other alternative.*

But will the preference of the median voter be the efficient level of spending? In this case yes, because $1200 is efficient. But the preference of the median voter is often *not* the efficient spending level. Suppose the third citizen's preferences were the same as the second's. Then, the median voter's choice would still be $1200 per pupil, but the efficient level of spending would be less than $1200 (because the efficient level involves an average of the preferences of all three citizens). In this case, majority rule would lead to too much spending on education. And if we reversed the example so that the first and second citizens' preferences were identical, majority rule would generate too little educational spending.

Thus, majority rule voting allows the preferences of the median voter to determine referenda outcomes, but these outcomes need not be economically efficient. Majority rule is inefficient because it weighs each citizen's preference equally-the efficient outcome weighs each citizen's vote by his or her strength of preference.

Summary

1. There is an externality when a producer or a consumer affects the production or consumption activities, of others in a manner that is not directly reflected in the market. Externalities cause market inefficiencies because they inhibit the ability of market prices to convey accurate information about how much to produce and how much to buy
2. Pollution is a common example of an externality that leads to market failure. It can be corrected by emissions standards, emissions fees, marketable emissions permits, or by encouraging recycling. When there is uncertainty about costs and benefits, any of these mechanisms can be preferable, depending on the shapes of the marginal social cost and marginal benefit curves.
3. Inefficiencies due to market failure may be eliminated through private bargaining among the affected parties. According to the Coase Theorem, the bargaining solution will be efficient when property rights are clearly specified, when transactions costs are zero, and when there is no strategic behavior. But bargaining is unlikely to generate an efficient outcome because parties frequently behave strategically.
4. Common property resources are not controlled by a single person and can be used without a price being paid. As a result of the free usage, an externality is created in which the current overuse of the resource harms those who might use it in the future.
5. Goods that private markets are not likely to produce efficiently are either nonrival or nonexclusive. Public goods are both. A good is nonrival if for any given level of production, the marginal cost of providing it to an additional consumer is zero. A good is nonexclusive if it is expensive or impossible to exclude people from consuming it.
6. A public good is provided efficiently when the vertical sum of the individual demands for the public good is equal to the marginal cost of producing it.
7. Majority rule voting is one way for citizens to voice their preference for public goods. Under majority rule, the level of spending provided will be that preferred by the median voter. This need not be the efficient outcome.

Questions for Review

1. Which of the following describes an externality and which does not? Explain the difference.
   a. A policy of restricted coffee exports in Brazil causes the U.S. price of coffee to rise, which in turn also causes the price of tea to increase.
   b. An advertising blimp distracts a motorist who then hits a telephone pole.

2. Compare and contrast the following three mechanisms for treating pollution externalities when the costs and benefits of abatement are uncertain: (a) an emissions fee, (b) an emissions standard, and (c) a system of transferable emissions permits.

3. When do externalities require government intervention, and when is such intervention unlikely to be necessary?

4. An emissions fee is paid to the government, whereas an injurer who is sued and is held liable pays damages directly to the party harmed by an externality. What differences in the behavior of victims might you expect to arise under these two arrangements?

5. Why does free access to a common property resource generate an inefficient outcome?

6. Public goods are both nonrival and nonexclusive. Explain each of these terms and state clearly how they differ from each other.

7. Public television is funded in part by private donations, even though anyone with a television set can watch for free. Can you explain this phenomenon in light of the free rider problem?

8. Explain why the median voter outcome need not be efficient when majority rule voting determines the level of public spending.

Exercises

1. A number of firms have located in the western portion of a town, after single-family residences took up the eastern portion. Each firm produces the same product and in the process emits noxious fumes that adversely affect the residents of the community.
   a. Why is there an externality created by the .firms?
   b. Do you think that private bargaining can resolve the problem with the externality? Explain.
   c. How might the community determine the efficient level of air quality?

2. A computer programmer lobbies against copyrighting software. He argues that everyone should benefit from innovative programs written for personal computers, and that exposure to a wide variety of computer programs will inspire young programmers to create even more innovative programs. Considering the marginal social benefits possibly gained by his proposal, do you agree with the programmer's position?

3. Four firms located at different points on a river dump various quantities of effluent into it. The effluent adversely affects the quality of swimming for homeowners who live downstream. These people can build Swimming pools to avoid swimming in the river, and the firms can purchase filters that eliminate harmful chemicals in the material that is dumped in the river. As a policy adviser for a regional planning organization, how would you compare and contrast the following options for dealing with the harmful effect of the effluent:
   a. An equal rate effluent fee on firms located on the river.
   b. An equal standard per firm on the level of effluent each firm can dump.
   c. A transferable effluent permit system, in which the aggregate level of effluent is fixed and all firms receive identical permits.

4. Recent social trends point to growing intolerance of smoking in public areas. Many people point out

the negative health effects of "second-hand" smoke. If you are a smoker and you wish to continue smoking despite tougher antismoking laws, describe the effect of the following legislative proposals on your behavior. As a result of these programs, do you, the individual smoker, benefit? Does society benefit as a whole?

a. A bill is proposed that would lower tar and nicotine levels in all cigarettes.

b. A tax is levied on each pack of cigarettes sold.

c. Smokers would be required to carry smoking permits at all times. These permits would be sold by the government.

5. A beekeeper lives adjacent to an apple orchard. The orchard owner benefits from the bees because each hive pollinates about one acre of apple trees. The orchard owner pays nothing for this service, however, because the bees come to the orchard without his having to do anything. There are not enough bees to pollinate the entire orchard, and the orchard owner must complete the pollination by artificial means, at a cost of $10 per acre of trees.

Beekeeping has a marginal cost MC = 10 + 2Q, where Q is the number of beehives. Each hive yields $20 worth of honey.

a. How many beehives will the beekeeper maintain?

b. Is this the economically efficient number of hives?

c. What changes would lead to the more efficient operation?

6. There are three groups in a community. Their demand curves for public television in hours of programming, T, are given respectively by

$$W_1 = \$150 - T$$

$$W_2 = \$200 - 2T$$

$$W_3 = \$250 - T$$

Suppose public television is a pure public good that can be produced at a constant marginal cost of $200 per hour.

a. What is the efficient number of hours of public television?

b. How much public television would a competitive private market provide?

7. Reconsider the common resource problem given in Example 185. Suppose that crawfish popularity continues to increase, and that the demand curve shifts from $C= 0.401 - 0.0064F$ to $C = 0.50 - 0.0064F$. How does this -shift in demand affect the actual crawfish catch, the efficient catch,and the social cost of common access? (Hint: Use the Marginal Social'Cost and Private Cost curves given in the example.)

8. The Georges Bank, a highly productive fishing area off New England, can be divided into two zones in terms of fish population. Zone 1 has the higher population per square mile but is subject to severe diminishing returns to fishing effort. The daily fish catch (in tons) in Zone 1 is

$$F_1 = 200(X_1) - 2(X_1)^2$$

where X_1 is the number of boats fishing there. Zone 2 has fewer fish per mile but is larger, and diminishing returns are less of a problem. Its daily fish catch is

$$F_2 = 100(X_2) - (X_2)^2$$

where X_2 is the number of boats fishing in Zone 2. The marginal fish catch MFC in each zone can be represented as

$$MFC_1 = 200 - 4(X_1)$$

$$MFC_2 = 100 - 2(X_2)$$

There are 100 boats now licensed by the U.S. government to fish in these two zones. The fish are sold at $100 per ton. The total cost (capital and operating) per boat is constant at $1000 per day.. Answer the following questions about this situation.

a. If the boats are allowed to fish where they want, with no government restriction, how many will fish in each zone? What will be the gross value of the catch?

b. If the U.S. government can restrict the boats, how many should be allocated to each zone? What will the gross value of the catch be? Assume the total number of boats remains at 100.

c. If additional fishermen want to buy boats and join the fishing fleet, should a government wishing to maximize the net value of the fish catch grant them licenses to do so? Why or why not?