

Public Goods and Externalities

How may public goods and externalities adversely affect the way resources are allocated by markets and what are the possible remedies, government regulation among others, to such impediments to economic efficiency?



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Learning Objectives

- Explain what economists mean by the term “public goods” and how the free-rider problem inhibits the provision of the efficient output of such goods.
- Define external benefits and external costs and show how their presence results in nonoptimal output levels for goods characterized by such aspects.
- Show how clearly defined and enforced property rights can resolve externality problems and thereby ensure an efficient outcome.
- Demonstrate how air pollution can more efficiently be controlled through the establishment of an overall industry pollution target and the assignment of tradeable emissions permits to the industry’s firms.

PUBLIC GOODS

those goods that benefit all consumers, such as national defense

EXTERNALITIES

the harmful or beneficial side effects of market activities that are not fully borne or realized by market participants

As we have seen in several of this book’s preceding chapters, government intervention in markets may fail to promote economic efficiency. For example, Chapter 10 showed how rent control and a quota on sugar imports can diminish the total surplus realized by market participants as a group. Without discounting the impediments to efficiency that may be associated with government intervention, this chapter looks at two important reasons why markets left to themselves may also not function efficiently: public goods and externalities. **Public goods** are those that benefit all consumers, such as national defense. A public good will be undersupplied by a market when consumers cannot be excluded from sharing in its benefits and thus have no incentive to pay for its production.

Externalities are present when all of the costs or benefits of a good are not fully borne by the participants in the market for it. For example, an oil refinery may not have to pay for some of the air pollution generated by its production process and may consequently produce

more oil than is economically efficient. Individuals may not obtain a flu shot if some of the benefits of the vaccination against such a communicable disease accrue to society at large rather than fully to them.

When public goods or externalities lead markets to generate an inefficient allocation of resources, government can intervene, at least in theory, with an appropriate policy that will improve things. This chapter analyzes how public goods and externalities may adversely affect the way resources are allocated by markets as well as the remedies, government regulation among others, to such impediments to economic efficiency.

20.1

WHAT ARE PUBLIC GOODS?

The term *public good*, as used by economists, does not necessarily refer to a good provided by the government. Instead, economists define a public good by the characteristics of the good itself. Two are important: nonrival consumption and nonexclusion.

A good is **nonrival in consumption** if, with a given level of production, consumption by one person need not diminish the quantity consumed by others. Although this definition may sound peculiar, such goods do exist. Consider a nuclear submarine that reduces the likelihood of enemy attack. Your property and person are protected, and so are others'. The protection you receive in no way diminishes the extent to which others are protected. Another example is a flood control project that reduces the probability of flood damage. Less flood damage to one home does not mean more flood damage to another; all persons in a given area simultaneously benefit in the form of a reduced likelihood of flooding.

In effect, nonrival consumption means potential simultaneous consumption of a good by many persons. By contrast, most goods are rival in consumption. For a given level of production of shoes (or soft drinks, T-shirts, cars, or hamburgers), the more you consume, the less is available for others. In these cases consumption is rival because the economic system must ration output among competing (rival) consumers. When a good is nonrival in consumption, the good need not be rationed. Once it is produced, the good can be made available to all consumers without affecting any individual's consumption level.

The second characteristic of a public good is nonexclusion. **Nonexclusion** means that confining a good's benefits (once produced) to selected persons is impossible, or prohibitively costly. Thus, a person can benefit from a good's production regardless of whether he or she pays for it. Although the concepts of nonrivalry and nonexclusion often go together, they are distinct. Nonrivalry means that consumption by one person *need not* interfere with consumption of others; although a good may be nonrival in consumption, restricting consumption to selected persons may still be possible.

For example, when a Web site is posted, anyone with Internet access can go to the Web site and view its contents without interfering with another person's ability to view the same site. (An exception would be if the site suddenly got a huge number of hits, overloading the server.) It is possible to deliberately exclude access to a Web site, however, and in fact, it is often done. The Web site for the *Wall Street Journal*, for instance, www.wsj.com, includes "Free Content" that may be accessed by anyone. However, only subscribers can access more detailed information, such as front-page stories from the *Journal*. Clicking on those areas brings up the message, "The page you requested is available only to subscribers." Subscribers must supply a user number and a password, and nonsubscribers are denied access. The Web illustrates how some things can be nonrival and yet have the possibility of exclusion. Thus, it does not meet the criteria to be a public good.

In contrast, national defense is an example of a good with both characteristics. A given defense effort protects (or endangers) everyone simultaneously, and to limit the protection to certain people is impossible. The benefits of defense are thus nonrival to the population, and exclusion of selected persons is infeasible.

NONRIVAL IN CONSUMPTION

a condition in which a good with a given level of production, if consumed by one person, can also be consumed by others

NONEXCLUSION

a condition in which confining a good's benefits, once produced, to selected persons is impossible or prohibitively costly

A good that is nonrival in consumption and has high exclusion costs creates problems for a market system. Once such a good is produced, many people will automatically benefit regardless of whether they pay for it, because they cannot be excluded. As we will see, this feature makes it unlikely that private producers will provide the good efficiently.

The Free-Rider Problem

Even when a public good is worth more to people than it costs to produce, private markets may fail to provide it. To see why, consider the construction of a dam that will lessen the probability of flooding for a community's residents; the dam is a public good for the residents. It may have a total cost of \$1,000,000, and business firms will be willing to build it if someone will provide the funds. If 10 persons live in the community and the benefit of the dam to each person is \$200,000, then the total benefit of the dam to all 10 residents is \$2,000,000—twice as much as it costs. All 10 people would be better off if each contributed \$100,000 to finance construction costs, since each would then receive a benefit valued at \$200,000 from the dam.

Even though it is in each resident's interest to have the dam built, there is a good chance that it won't be built if private markets are relied upon to organize the construction. To finance the dam, residents must jointly agree to contribute, but many will realize that they get the benefit of the dam once built, regardless of whether they contribute toward its construction. *Each resident, therefore, has an incentive to understate what the dam is worth in an effort to secure the benefit at a lower, or zero, cost.* If enough people behave this way—as a **free rider**—voluntary contributions will be insufficient to finance the dam and it won't be built. Viewing the provision of public goods as a prisoner's dilemma, free riding is the equivalent of “cheating” in the prisoner's dilemma game discussed in Chapter 14.

When public goods are involved, free riding is rational, but it hinders the ability of private markets to cater efficiently to the demand for a public good. In the example just discussed, enough people could conceivably contribute so that the dam would be financed by voluntary agreements. With just 10 people involved, only a small number need to agree to contribute. The severity of the free-rider problem, however, varies with the number of people involved. The larger the number of people receiving benefits from a public good, the less likely that voluntary cooperation will ensure its provision.

As the group size increases, it is more likely that everyone will behave like a free rider, and the public good will not be provided. To illustrate, let's change our example slightly and assume that a dam now benefits 1,000 people, each by \$2,000. (Note that the total benefit is still \$2,000,000, just as before.) In this case, faced with deciding whether or how much to contribute voluntarily, each person will realize that one single contribution has virtually no effect on whether the dam is built. Put differently, the outcome depends mainly on what the other 999 people do, and whether any one person contributes will not affect the others' decisions. In this case each person gets the same benefit whether or not any contribution is made, and choosing not to contribute is the most rational behavior. Because this is true for everyone, few people will contribute, and the good likely will not be provided.

Many real-world examples provide evidence of free-rider behavior with public goods. A particularly clear-cut example occurred in 1970 (before mandatory pollution controls) when General Motors tried to market pollution control devices for automobiles at a price of \$20. The emission controls would have reduced the pollution emitted by 30 to 50 percent. Pollution abatement is, of course, a public good, at least over a certain geographic area. It is reasonable to suppose that the benefits of a 30 to 50 percent reduction in automobile pollution far outweighed the cost of \$20 per car. Yet GM withdrew the device from the market because of poor sales. This example illustrates the large-group free-rider problem at work. Everyone might have been better off if all drivers used the device, but it was



FREE RIDER

a consumer who has an incentive to underestimate the value of a good in order to secure its benefits at a lower, or zero, cost

not in the interest of any single person to purchase it because the overall level of air quality would not be noticeably improved as a result of any one individual's action.

When the benefits of a public good are nonrival over a large group, private markets probably will not provide it. Even if some amount of the public good is provided through the contributions of a few people, it will be at a suboptimal quantity. This result is true even when it is in the interest of people to have the good provided—that is, even when the benefits exceed the costs. Competitive markets cannot in general supply public goods efficiently. This fact provides a major justification for considering governmental alternatives. In the dam example of 1,000 persons, for instance, the government could levy a tax of \$1,000 on each person and use the \$1,000,000 in tax revenue to finance the dam. Each person would be made better off by this policy, receiving \$2,000 of benefit from the dam at a cost of \$1,000 in taxes. The government expenditure of \$1,000,000 on the dam would lead to a more efficient allocation of resources than reliance on private markets.

APPLICATION 20.1

AN ONLINE HORROR TALE

In 2000, horror writer Stephen King became the first major author to self-publish online.¹ King asked readers to pay him a dollar for each chapter of a serial e-novel, titled “The Plant,” they downloaded and

warned that he would not post new installments unless he received payments for at least 75 percent of the downloads. Voluntary contributions for King's e-novel appeared to be plagued by the free-rider problem as only 46 percent of the downloads were paid for. King promptly called it quits on publishing “The Plant” online in order to work on other, more conventional books from which it is easier to exclude non-payers.

¹“A Stephen King Online Horror Tale Turns Into a Mini-Disaster,” *New York Times on the Web*, November 29, 2000.

20.2

EFFICIENCY IN THE PROVISION OF A PUBLIC GOOD

What is the efficient output of a public good? As usual, we must compare the marginal benefit and marginal cost associated with different levels of output. The marginal cost of a public good is the opportunity cost of using resources to produce that good rather than others, just as it is in the case of the nonpublic, or private, goods discussed in previous chapters. Because of the nonrival nature of the benefits of a public good, though, its marginal benefit differs from that of a private good. With a good like a cheeseburger, the marginal benefit of producing an additional unit is the value of the cheeseburger to the single person who consumes it. With a public good like defense, the marginal benefit is not the marginal value to any one person alone because many people benefit simultaneously from the same unit. Instead, we must add the marginal benefits of every person who values the additional unit of defense, and the resulting sum indicates the combined willingness of the public to pay for more defense—that is, its marginal benefit.

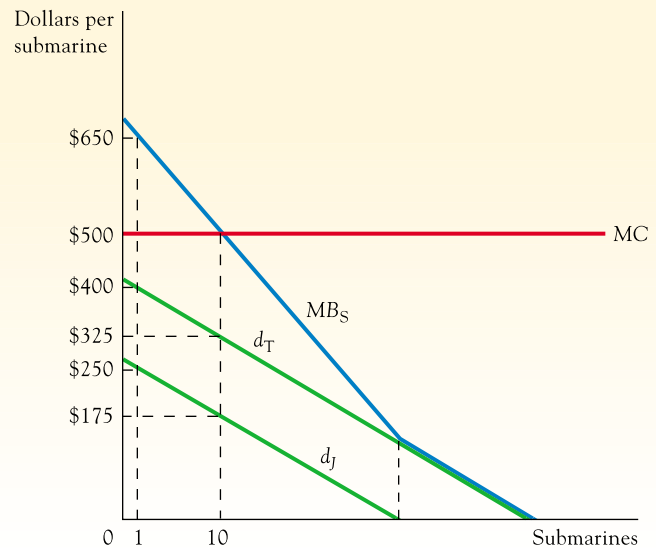
Figure 20.1 shows how we derive the demand, or **social marginal benefit curve** for a public good like submarines. For simplicity, assume that only two people, Ted and Jane, benefit from the defense services of submarines. Each person has a demand curve for submarines, shown as d_T and d_J . These demand curves are derived from each person's indifference curves, just as would their demand curves for a private good. Recall that the height of a consumer's demand curve indicates the marginal benefit of another unit of the good. *To derive the social, or combined, demand curve, we must add the marginal benefits of the two consumers.* Geometrically, the combined de-

SOCIAL MARGINAL BENEFIT CURVE
the demand curve for a public good

FIGURE 20.1

The Efficient Output of a Public Good

Because the benefits of a public good are nonrival, the social marginal benefit is the sum of the marginal benefits of the separate consumers. Graphically, the social marginal benefit curve is constructed by vertically summing the consumers' demand curves. The efficient output is identified by the intersection of MB_S and MC .



VERTICAL SUMMATION (OF DEMAND CURVES)

the derivation of a social marginal benefit curve through the summing of consumers' marginal benefit curves

mand curve involves a **vertical summation** of the consumers' demand curves. For example, the marginal benefit to Ted of the first submarine (\$400) is added to the marginal benefit Jane receives from the first submarine (\$250) to determine the social marginal benefit (\$650) for the first unit. This vertical addition of marginal benefits identifies one point on the social marginal benefit curve, indicating that the combined marginal benefit of Ted and Jane for the first submarine is \$650. At alternative quantities of submarines, we continue to add the heights of each consumer's demand curve to trace out the entire social marginal benefit curve, MB_S .

We can now determine the efficient output of submarines. At any output where MB_S lies above the marginal cost curve MC —drawn here for simplicity as horizontal at \$500—Ted and Jane are willing to pay more for the unit than its marginal cost, so efficiency requires a higher output. Thus, an additional unit could be financed in a way that makes both of them better off—with each contributing somewhat less than the maximum amount they are willing to pay. When MC lies above MB_S , however, too much of the public good is being produced—the combined marginal benefit as shown by MB_S is less than marginal cost over this output range. Thus, the efficient output is 10 submarines, where Ted's marginal benefit of \$325 plus Jane's marginal benefit of \$175 just equals the marginal cost of \$500.

In general, the efficient output of a public good occurs where MB_S , obtained by vertically summing the demand curves of all consumers, intersects the marginal cost curve. There is no presumption, however, that this output will be the actual output. In fact, we have already seen that the free-rider problem generally means that private markets will not produce the efficient output. The government has the power to finance the efficient output from tax revenues, but whether it actually does so depends on how political forces determine public policy.

Government financing of a public good overcomes one aspect of the free-rider problem—the tendency of people to withhold payment. There is another aspect of free riding that government financing does not overcome: people have no incentive to accurately reveal their demands for the public good—especially if they will be taxed commensurate to the benefits they report receiving. To determine the efficient output, we must know every person's demand curve so that we can vertically add them to obtain MB_S . How can we determine the true worth of a public good like defense to millions of people? Needless to say, obtaining this information is problematic.

For example, to obtain the efficient output level of a public good such as the one depicted in Figure 20.1, the government can tax people according to the heights of their reported marginal benefit curves. Thus, for 10 submarines, Ted and Jane are taxed \$325 and \$175 per unit, respectively. The total amount paid in taxes (\$500 per submarine) is just sufficient to cover the marginal cost of producing an additional submarine at the efficient output of 10.

Where citizens are taxed according to their reported marginal benefit curves, however, they have an incentive to understate their benefits. For example, Jane may be tempted to say that she gets no benefit from submarines (and thus pays no taxes) and free ride on any payments made by Ted—since any submarines Ted pays for through taxes also benefit Jane. Ted has the same incentive to understate the benefit he gets from submarines. Understatement of demand implies suboptimal provision of the public good.

APPLICATION 20.2

PROMOTING TRUTHFUL REVELATION IN CHINA

In the early 1900s, the government of China used the value of a citizen's house and land-holdings as a proxy to determine the tax levied for benefits derived by the citizen from the public goods provided by the government. To promote truthful reporting by citizens of the value of their property, the Chinese government em-

ployed a creative enforcement mechanism. It reserved the right to purchase a citizen's property at the value of the property reported by the citizen for tax reasons. Any incentive to understate property values for tax reasons thus was counteracted by the potential that one's property could be confiscated at a loss by government authorities.

Efficiency in Production and Distribution

In Chapter 19, we pointed out that there are three conditions for efficiency. These conditions also apply to public goods. So far, we have emphasized only the condition for an efficient level of output. A second condition is that the output be produced by using the least costly combination of inputs. In Figure 20.1, that condition is implicit in the assumption that a marginal cost of \$500 is the minimum cost necessary to produce a submarine. The third condition relates to the efficient distribution of the good among consumers. For a private good this condition requires an equality of marginal rates of substitution. But how is a public good rationed efficiently?

With a public good there is no rationing problem. If 10 submarines are produced, both Ted and Jane simultaneously benefit, and the benefit to one in no way diminishes the benefit to the other. For example, suppose it were possible in some hard-to-imagine way to have Ted protected by 10 submarines but Jane protected by only 5. In other words, if exclusion were possible, would there be any advantage in excluding Jane from the services of all 10 submarines? The answer is no, because when 10 submarines are available, Jane's receiving the services of only 5 does not make any more submarines available for Ted. Consequently, Jane is harmed, and no one benefits. By definition, this outcome is clearly inefficient.

Recall our definition of a public good as one characterized by nonrival consumption and nonexclusion. When a good has both characteristics, it would be impossible to exclude anyone from its benefits, even if we wanted to. What about a good with nonrival benefits where exclusion is possible? The analysis above suggests that *it is inefficient to exclude anyone even if we could*. Before accepting that as a general rule, let's examine an important public policy issue dealing with a good where benefits are nonrival but exclusion is possible.

Patents

As explained in Chapter 11, a patent grants temporary legal monopoly power to an inventor. A patent gives the inventor the right to make and sell some new product or to use some new production process for a period of 17 years. But what do patents have to do with the exotic world of nonrival benefits and nonexclusion? Surely, you say, a vibrating toilet seat (patent number 3,244,168, granted in 1966) is not a public good.

Admittedly, most of the products granted patents are not themselves public goods. But what about the knowledge required to make, for example, a vaccine to prevent AIDS? This knowledge of “how to do it” has nonrival benefits. Once the knowledge exists, any number of people can use it without interfering with each other’s use. One person’s use of this special knowledge does not leave less for someone else. Simultaneous consumption of knowledge is therefore possible, but could people be excluded from its use? Whether exclusion is possible depends on the type of knowledge involved, but in some cases the use of knowledge can be prohibited if producing or selling its tangible embodiment is made illegal. For example, if it is illegal for you to manufacture and sell the AIDS vaccine, you would be effectively excluded from using the knowledge of how to make it. This is exactly what patents do. They exclude all but the inventor from making use of the knowledge he or she produced.

Thus, at least some types of knowledge have nonrival benefits, but exclusion is possible. Now let’s consider efficiency in resource allocation in connection with knowledge. Although new knowledge is sometimes produced by accident, much of it results from expenditures on research and development. In making such expenditures, the efficient output of new knowledge requires that resources be devoted to producing it and is accomplished by equating the vertically summed marginal benefits with marginal cost, just as in Figure 20.1. Yet once the knowledge exists, using it efficiently requires that no one be excluded. Both aspects of efficiency are important.

To see how this discussion relates to patents, suppose that the inventor of an AIDS vaccine could not exclude others from copying and selling the product. Would the inventor devote a million dollars to develop such a vaccine? If this investment were successful, others would immediately copy and sell it, driving the price down to a level that just covered production cost and leaving no way for the inventor to recoup research costs. For this reason inventors would have little financial incentive to produce the knowledge in the first place, even though that knowledge might be highly beneficial. Too few resources would be devoted to research and development, because those who bear the costs could not charge others who use the knowledge for the benefit they receive. In other words, private markets would not produce the efficient quantity of the public good, new knowledge.

Patents can encourage a greater, more efficient output of new knowledge. Because inventors receive a temporary monopoly right, they get a return above the cost of producing new products to compensate for the research costs. The prospect of this gain stimulates inventors to devote resources to the production of new knowledge. This example illustrates how private markets can produce a good with nonrival benefits when exclusion is possible.

Encouraging a greater, more efficient output is the beneficial result of using patents, but there is a cost. Once the new knowledge is produced, it is inefficiently employed, since some people are legally excluded from using it. That is, the AIDS-preventing vaccine will be monopolistically produced for 17 years, which inefficiently restricts the use, or consumption, of the vaccine. This cost must be weighed against the gain—namely, that the vaccine might never have been developed without the incentive created by patent protection.

Private markets can produce goods with nonrival benefits when exclusion is possible, as the patent example shows. Private markets, however, do not function with perfect efficiency because of the exclusion of some people who could potentially benefit. Whether it is possible to devise a better arrangement is uncertain and requires a more detailed case-by-case evaluation. In any event, the degree of inefficiency in market provision for a nonrival good will be far less when exclusion is possible than when it is not. The combination of the

nonrival and nonexclusion characteristics creates more severe problems for market provision, and in this case a more active role for government may be required. No one has determined, for example, how national defense could be provided by private markets.

APPLICATION 20.3

NAPSTER: NIPPING OR NUDGING ECONOMIC EFFICIENCY?

Copyrights are intended to encourage the production of music, literature, and art by granting creators an exclusive right to publish, sell, and reproduce their works for a set time period. Like patents, copyrights require a dynamic versus static efficiency trade-off. This is because while copyrights promote the production of music, literature, and art from a dynamic perspective, once a work has been produced, copyrights also exclude some people who might benefit from hearing a particular song or reading a given novel.

Napster provides a recent example of the (sometimes subtle) efficiency considerations associated with copyrights.² The brainchild of 18-year-old college drop-out Shawn Fanning, Napster was launched in 1999 as an Internet service letting users download songs at no charge from other users' hard drives. The first example of a peer-to-peer (P2P) Internet service, Napster acquired 25 million users within a year of its inception and quickly drew the attention of the \$40-billion-in-annual-revenues music industry.

Represented by the Recording Industry Association of America (RIAA), the music industry argued that Napster facilitated the theft of musical property, had cost the industry more than \$300 million in lost sales as of the year 2000, and should be shut down. The band Metallica and rapper Dr. Dre brought lawsuits against Napster for copyright infringement. In support of the argument that Napster would diminish the incentive to produce music, the RIAA presented evidence from retail-store tracker SoundScan. The evidence showed that compact disc sales fell in the year 2000 by 13 percent at stores within one mile of *Wired* magazine's Top-40 "wired" colleges and those near colleges with Napster-induced network overloading problems.

Not all artists, however, opposed the continued growth of Napster. In fact, the band Limp Bizkit and

rapper Chuck D. argued that Napster would spur sales revenue by providing a try-before-you-buy service to individuals who might not otherwise become exposed to a particular artist's work. Chuck D. pointed to overall compact disc sales growing by \$500 million in 2000, the same year that witnessed the dramatic increase in users of Napster and rival P2P service providers such as Gnutella and Aimster.

Indeed, it could be argued that the lower reproduction and distribution costs brought about by the Internet and technological innovations such as Napster may, over the long run, represent more of an opportunity than a threat to the music industry. By analogy, economists Hal Varian and Carl Shapiro of the University of California at Berkeley point out that, contrary to leading to the demise of the movie industry as initially predicted, video cassette recorders have proven to be a boon to it. Similarly, the Internet and technological innovations such as Napster promise to broaden the market for music. Industry sales and profits thus may increase as long as producers are adept at setting the terms and conditions that maximize the value of their intellectual property—that is, as long as exclusion remains possible.

The music industry succeeded in getting Napster shut down through a court order in July 2001 because Napster operated central servers that tracked and controlled the transfer of files between users. However, new file sharing services, such as KazaA, Grokster, and Morpheus, soon sprang up and the same legal objections that felled Napster could not be raised. This is because KazaA, Grokster, and Morpheus provide software that individual digital-music fans can use to access MP3 files from other users with the same software. Given that KazaA, Grokster, and Morpheus had a combined total of 70 million users by the fall of 2002 (three times as many as Napster in its heyday), the challenges they pose for, or perhaps, the opportunities they bring to the music industry appear to be significant.

²This application is based on: Carl Shapiro and Hal R. Varian, *Information Rules* (Boston: Harvard Business School Press, 1999); and "The New Napsters," *Fortune*, August 12, 2002, pp. 115–116.

20.3

EXTERNALITIES

EXTERNAL BENEFITS

positive side effects of ordinary economic activities

EXTERNAL COSTS

negative side effects of ordinary economic activities

Sometimes, in the process of producing or consuming certain goods, harmful or beneficial side effects called externalities are borne by people not directly involved in the market exchanges. These side effects are called **external benefits** when the effects are positive and **external costs** when they are negative. The term *externality* is used because these effects are felt beyond, or are external to, the parties directly involved in generating the effects.

Immunization against a contagious disease is a good example of a consumption activity that involves external benefits. For instance, if Barney decides to get an inoculation, he benefits directly because his chance of contracting the disease is reduced. This benefit is not the external benefit, since Barney himself receives it. The external benefit is the one other people receive in the form of a reduced likelihood they will catch the disease because an inoculated Barney is less likely to transmit it. The central point is that Barney's decision about whether to be inoculated is unlikely to be swayed by how his inoculation affects other people: he is concerned mainly with the effect on his own health. Thus, the benefit his inoculation creates for others is external to, and doesn't influence, his decision.

Pollution provides a classic example of an external cost. Driving a car or operating a factory with a smoking chimney pollutes the atmosphere that others breathe; thus, the operation of a car or factory imposes costs on people not directly involved in the activity. Similarly, operating a boom box or motorcycle produces a level of noise that is often irritating to those nearby, just as the noise level of an airplane may be annoying to people living near airports. Congestion is also an external cost: when a person drives during rush hour, the road becomes more congested, not only for this person but for other drivers as well.

At a formal level, externalities and public goods are very similar, and recognizing the similarity makes understanding externalities easier. If Barney is inoculated against a contagious disease, there are nonrival benefits: both he and others simultaneously benefit from his inoculation. In addition, to exclude other people from the benefits would be very difficult. When a person produces new knowledge, this action confers an external benefit on others who can use the knowledge profitably. Pollution is also like a public good (except here it should perhaps be called a public bad) since there are nonrival costs. A large number of people are simultaneously harmed if the atmosphere is polluted, and, obviously, to have the atmosphere in a particular area polluted for some and not for others would be difficult. The sole distinction between externalities and public goods is that external effects are *unintended* side effects of activities undertaken for other purposes. People don't pollute because they enjoy breathing polluted air; they simply want to transport themselves conveniently in a car from one place to another.

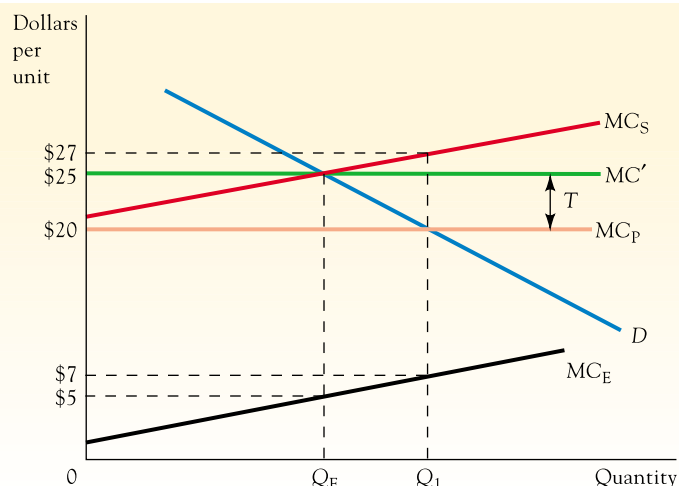
Externalities are likely to lead to an inefficient allocation of resources, just as public goods do. Market demands and supplies will reflect the benefits and costs of market participants only; the benefits and costs that fall on others will not be taken into account in determining resource allocation. For example, Barney may decide against being inoculated because the improvement in his health is not worth the extra cost. If the benefits of improved health for others are added to his benefit, the combined benefit might exceed the cost. In this case Barney's decision to not be inoculated would represent an inefficient use of resources.

External Costs

A closer look at a case involving external costs will help clarify the issues involved. Suppose that firms in a constant-cost competitive industry produce some type of waste materials as a byproduct of their activities. They dispose of these wastes by dumping them in a nearby river. From the firms' point of view, this method of disposal is the least costly. People living downstream, however, suffer, because the river no longer serves recreational purposes. The firms impose external costs on those living downstream. Because these external costs are not taken into account by the firms, the allocation of resources is inefficient.

FIGURE 20.2**External Costs and Taxes**

The marginal external cost curve, MC_E , shows the external cost associated with production of the good. Vertically adding this curve to the private marginal cost curve, MC_P , yields the social marginal cost curve, MC_S . Its intersection with the demand curve identifies the efficient output, Q_E , which is less than the market equilibrium output, Q_1 .



Let's see how this situation appears diagrammatically. In Figure 20.2, the competitive demand and supply curves, where of course the supply curve is the private marginal cost curve, are D and MC_P . The equilibrium output is Q_1 with a price of \$20 per unit. Each unit of output generates a specific quantity of wastes, so the greater the industry output, the greater the amount of water pollution. The harm done by the pollution is shown by the marginal external cost, or MC_E , curve. It slopes upward, reflecting the assumption that additional amounts of pollution inflict increasing costs on people living downstream. (The marginal external cost curve results from vertically summing the marginal cost of each person harmed, since the harmful effects are nonrival over many persons.) At the market output of Q_1 , the marginal external cost is \$7, implying that people downstream would be \$7 better off with one unit less of the product and the waste associated with it.

With external costs, the competitive output is too large from a social perspective. Firms expand output to where the price consumers pay just covers *their* private production costs (as reflected by the private marginal cost curve, MC_P), but the resulting price does not cover *all* costs, since pollution is also a cost of producing the product. At Q_1 , firms incur a cost of \$20 per unit, which is just covered by the price paid by consumers, but there is also a \$7 per-unit pollution cost borne by people downstream. At the competitive output, Q_1 , the product is not worth what it costs to produce. The social, or combined, marginal cost of production is \$27, while the marginal benefit to consumers is only \$20. The social marginal cost is shown by the curve MC_S , obtained by vertically summing the MC_E curve and the private marginal cost curve, MC_P . It identifies all the costs associated with producing the product, not just the costs borne by producers. Efficiency requires that output be expanded to the point where the marginal benefit to consumers equals the social marginal cost of production. This point is shown by the intersection of D and MC_S at an output of Q_E .

Competitive market pressures, however, lead to an output of Q_1 , larger than the efficient output. The government can do several things to improve the situation. One approach would be to levy a tax on the product to induce firms to produce at the efficient level. A tax of \$5 per unit would shift the private marginal cost curve up by \$5 to MC'_P , and firms would curtail production to Q_E , with consumers paying a price of \$25. The result is the efficient output level, where the marginal benefit to consumers equals the social marginal cost of production. Note that pollution is not completely eliminated; it is simply reduced to the point where a further reduction in production and pollution would cost more than it is worth. In general, external costs should not be totally eliminated even though those who are harmed

might like to see them reduced to zero. Instead, the gain from reduced pollution to people downstream must be weighed against the cost to consumers of reduced output.

In this example we assumed that each unit of output is invariably associated with a certain amount of pollution. In the more general case the amount of pollution per unit of output is variable. Automobiles, for example, can produce various amounts of emissions. When this situation is the relevant case, as it usually is, the tax should be levied on pollution itself, not on the product. Then, as discussed in Chapter 8, firms have an incentive to curtail pollution—the external cost—in the least costly manner.

APPLICATION 20.4

TRAFFIC EXTERNALITIES: THEIR CAUSES AND SOME POTENTIAL CURES

While an individual motorist's decision to drive at rush hour may cost only a few extra minutes of commuting time, the external congestion costs imposed by such motorists as a group can add up to millions of dollars per year in a major urban area. As noted in Application 1.3, an average driver in the Los Angeles area spends 56 hours a year stuck in traffic at a cost of \$1,000 per person in wasted time and gas.³

Beyond congestion costs, rush-hour commuters pay for only a fraction of what they impose on the community at large in terms of road construction and pollution costs. For example, significant road construction subsidies exist to better accommodate the needs of rush-hour drivers. According to one study, the subsidy totals \$500 annually per rush-hour commuter in the Los Angeles area. Overall, California state gasoline taxes amount to only one-sixtieth of the estimated cost that rush-hour drivers impose on the community at large in terms of congestion, road construction, and pollution costs.

Some examples from overseas suggest mechanisms by which motorists could be held more fully accountable for the burden they impose on a community. Hong Kong, for example, undertook an electronic road pricing experiment in the mid-1980s. Cars were equipped with an electronic license plate (at a cost of \$20 each) making them automatically detectable to computerized sensors located throughout the city's streets. A computer recorded their movements and tallied the tolls exacted on different city streets, billing car owners monthly based on streets traveled, days of the week, and times of day.

Singapore's efforts to control traffic are legendary for promoting free-flowing roads and cleaner air and

also for their draconian methods of enforcement. Whereas the neighboring capitals of Southeast Asia such as Bangkok, Thailand, and Jakarta, Indonesia, are notorious for their smog and day-long gridlock, Singapore's policies keep the skies clean and rush-hour traffic delays to a minimum. Among the policies is a requirement that cars entering the city center pay an Electronic Road Price (ERP) that varies in amount depending on the time of day. For example, the ERP is: \$2.50 from 8–9 AM; \$2 for 9–9:30 AM and 6–6:30 PM; \$1.50 from 5:30–6 PM; \$1 from 9:30–10 AM, 12:30–5:30 PM, and 6:30–7 PM; \$0.50 from 7:30–8 AM; and free at all other times.

The government of Singapore also adds on more than 200 percent in duties to every auto's purchase price. Moreover, every car owner must pay a sizable annual road use tax (analogous to a registration fee in the United States) to operate a vehicle. The road tax on a small Toyota is \$800. When even the sizable costs of purchasing an automobile failed to curb the growth in car ownership, Singapore began limiting the absolute number of cars that can be sold in any year to 50,000. The quota is designed to keep new purchases to 4 percent of the total cars on the road.

The top speed limit on the island of Singapore is set at 45 miles per hour, to promote safe driving and thereby minimize the chance of accident-related traffic jams. Taxis are required to have a chime built into their dashboards that sounds continuously and annoyingly when the speed limit is violated. Trucks are mandated to have a yellow light on their roofs that is activated when the speed limit is exceeded. Police, as well as hidden cameras hooked up to remotely operated radars, are employed to catch traffic violators. If speeding is caught on camera, a ticket is sent to the violator by mail within days of the infraction.

³This example is based on "In Singapore Driving a Car is Easy but Owning a Car Isn't," *Los Angeles Times*, August 17, 1991, pp. A1 and A14; and www.gov.sg/ta/2_ERP/Main.html.

APPLICATION 20.5

NON-FREE CALIFORNIA FREEWAYS

In recent decades, the price of highway construction in the United States has skyrocketed while the state and federal gasoline tax revenues used to finance such construction have diminished (because of improvements in the fuel efficiency of automobiles). In light of these trends, questions have begun to emerge whether American drivers will be able to continue relying on the government to provide free use of a sufficiently uncongested highway system that keeps pace with a growing population.

To address the dilemma, Orange County in Southern California began building a series of toll roads in the mid-1990s that could be a model for future highways.⁴ The plan is for the toll roads to be paid for by the drivers who use them. That is, individual drivers confront a system of “congestion prices” that vary from 25 cents to \$5 per use depending on both the length of the particu-

lar toll road and the amount of other traffic on the road. The congestion prices are adjusted continuously, ease of use is promoted through automation (cars can be equipped with transponders that automatically bill drivers’ accounts for usage and thus do not require stops at toll plazas), and carpooling is encouraged (through a price of zero).

Critics liken the experimental toll roads to a polite form of “highway robbery.” One policymaker has bemoaned the attempt to chip away at the concept of free roads, one of the last things shared equally by the rich and the poor. He goes on to argue, “I don’t like special roads being developed for richer people, while ordinary people end up with potholes and congestion.”

Most drivers, however, seem to accept the concept as a means to ensure continuation of the California lifestyle they have come to expect. As one legal secretary who uses the toll road almost daily puts it, “I love it... It’s expensive, but when you measure that against the frustration of being stuck on the freeway, it’s worth it. It’s cheaper than therapy.”

⁴This application is based on “Tolls Seen as Road to Expansion,” *Los Angeles Times*, March 23, 1997, pp. A3 and A29.

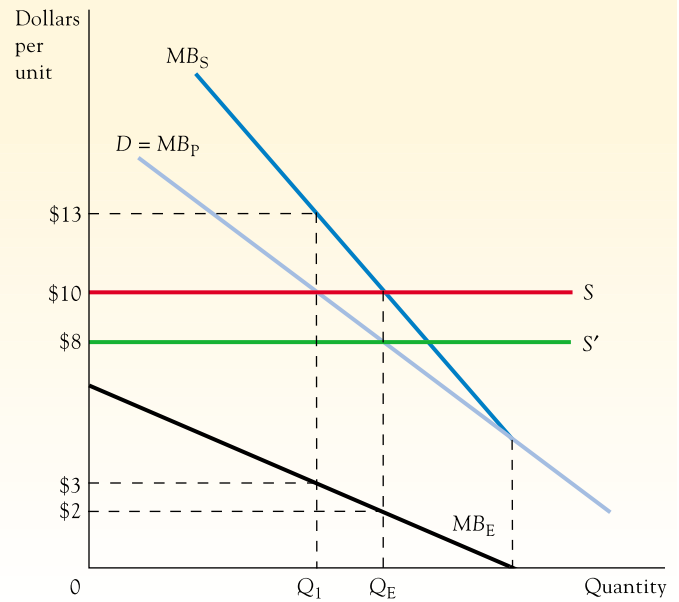
External Benefits

External benefits can be analyzed in a similar fashion. Let’s suppose that the consumption of some product generates external benefits—that is, people other than the direct consumers of the product benefit from its consumption. Some economists have argued that education may be such a product if a better-educated citizen not only makes himself or herself better off in the process but also the society of which he or she is a part. In Figure 20.3, the competitive supply and demand curves where demand identifies the private marginal benefit, are S and MB_P . The private marginal benefit curve, MB_P , reflects the marginal benefits of the good only to the consumers of the product, and its intersection with the supply curve determines the market equilibrium with an output of Q_1 and a price of \$10. The marginal external benefit curve, MB_E , shows the external benefits per unit of consumption. This curve is derived by vertically summing the demands of people other than the immediate consumers of the product. Vertical summation is used because people other than direct consumers simultaneously receive benefits—that is, the benefits are nonrival.

When external benefits exist, the competitive output is inefficient. At Q_1 , the marginal benefit to consumers of another unit of the product is \$10, as given by the height of the MB_P curve. If another unit is consumed, people other than the direct consumers also receive a marginal benefit valued at \$3, as shown by the height of MB_E at Q_1 . Thus, the combined marginal benefit for all those affected by consumption of another unit is \$13, and this amount exceeds the \$10 marginal cost of producing an additional unit. The combined, or

FIGURE 20.3**External Benefits and Subsidies**

The marginal external benefit curve, MB_E , shows the external benefits generated by consumption of the good. Vertically adding this curve to the private marginal benefit curve, MB_P , yields the social marginal benefit curve, MB_S . Its intersection with the supply curve identifies the efficient output, Q_E , which is greater than the market equilibrium output, Q_1 .



social, marginal benefit is shown by MB_S , which is derived by vertically adding MB_P and MB_E (again because the benefits are nonrival).⁵ The competitive output is too small because the marginal benefit of additional units of output exceeds the marginal cost of producing them. Yet there is no tendency for competitive pressures to produce a larger output, because the additional benefit to the direct consumers is less than the \$10 price they must pay per unit. Thus, it is not in the consumers' interest to purchase more than Q_1 units; only when the *combined* benefits to consumers and other people are considered is it apparent why greater production is worthwhile.

Figure 20.3 illustrates the general tendency of an activity to be underproduced when external benefits are involved and when production is determined in competitive markets. The competitive output is Q_1 , whereas the efficient output is Q_E , where MB_S intersects S . To achieve the efficient output, the government could step in with a policy designed to increase output beyond the market-determined level. In this case, a subsidy would be appropriate. If the government pays firms \$2 for every unit of output sold, the supply curve confronting consumers would shift to S' . Although the marginal cost of production is still \$10, the government in effect bears \$2 of the cost through the subsidy, so consumers pay only \$8. At the lower price, consumers purchase Q_E units, the efficient output.

20.4**EXTERNALITIES AND PROPERTY RIGHTS**

External effects may appear intrinsically different from normal costs and benefits, but that appearance is partly misleading. When a firm uses your labor services, it imposes a cost on you, since you sacrifice the option to use your time in other ways. When a firm pollutes the

⁵At an output in excess of the level at which the marginal external benefit becomes zero, the MB_S and MB_P curves coincide. When consumption is so great that additional consumption yields zero marginal benefits to other people, the only ones who receive any benefits from further increasing consumption are the direct consumers themselves, and their marginal benefits are shown by the MB_P curve.

river passing by your home, it imposes a cost on you, since you sacrifice the option to use the river for recreation. These costs are not fundamentally different: they both imply that you are unable to use economic resources in other, valuable, ways. Why, then, do we call pollution, but not the firm's employment of your labor services, an external cost?

One glaring difference in these two cases is that the firm must pay you for your labor services, but you are not compensated when the river is polluted. Since the firm must pay you at least enough to persuade you to give up alternative uses of your time, it will have an incentive to take this cost into account in deciding whether to employ you; that is, when the firm bears a direct cost associated with the use of a resource, that cost enters into its production decision. But if the firm can use the river in a way that harms you without compensating you for the damage, it has no reason to consider this cost in making its output decision—the firm treats the river as a zero-priced input.

Why must the firm pay to use your labor services but not to use the river? Fundamentally, the answer to this question involves property rights to the use of economic resources. You have well-defined and legally enforceable rights to your own labor services, meaning that no one can use them without securing your permission, which is normally acquired by paying you. There are, however, no such clearly defined property rights to the water that flows past your home. In fact, ownership of the river and who has the right to decide how it will be used are uncertain. Consequently, the firm can use it as a convenient garbage dump. If you had property rights to pure water flowing past your home, the firm would have to buy your permission to dump waste in the river. The firm might still pollute, but would do so only if the gain from polluting was greater than the compensation required to be paid. The situation would then be just analogous to the case of labor services. Pollution would no longer be a cost external to the firm's calculations; the cost would be taken into account, and the allocation of resources would be efficient.

Reasoning along these lines suggests that externalities are intimately connected with the way property rights are defined. Indeed, in most cases dealing with externalities, we can usually trace the source of the problem to an absence or inappropriate assignment of property rights. Accordingly, the government may not need to use taxes, subsidies, or regulation at all; it may only have to define and enforce property rights, and the resulting market exchanges will produce an efficient resource allocation.

As an example, imagine a beautiful beach on the California coast and suppose that no one owns it, just as no one owns the river. How will this scarce economic resource be used? It is not beyond fancy to conceive of masses of people crowding the beach trying to enjoy the sand, sun, and surf. Radios could blare, dune buggies roar up and down the beach, dirt bikes spray sand, litter lie strewn across the beach, and surfboards crash into swimmers. Externalities would be rampant.

Most would agree that this is not an efficient use of scarce oceanfront property, but because no one owns it, no one has an incentive to see the beach used in the most valuable way. The situation is far different when someone has property rights to the beach. In that case, use of the property will be guided by whoever pays the most for its use—that is, by who benefits most. The owner may still use the property as a beach, but now it will be operated differently. Admission might be charged, which will diminish the overcrowding that reduces the attractiveness of the nonowned beach. The owner might enforce rules regarding radios, litter, surfboards, and so on, further enhancing the benefits to consumers. In short, the external cost is no longer external when someone owns the beach. The owner has an incentive to see that the beach yields as much benefit to consumers as possible, since they will then pay more for its use.

The beach example is hypothetical, but it helps explain why some highways, parks, and beaches are overcrowded and inefficiently utilized. "Publicly owned" property is, in effect, sometimes owned by no one, in the sense that no one has the incentive and the right to see that it is used in the most valuable way.

APPLICATION 20.6**RADIO WAVES AND PROPERTY RIGHTS**

Radio began to be used commercially near the beginning of the twentieth century. In the early years there was no government involvement at all. Anyone who wanted to broadcast a message could build or buy a transmitter and broadcast on any frequency. The result was described by one observer as follows:

The chaos . . . as more and more enthusiastic pioneers entered the field of radio was indescribable. Amateurs crossed signals with professional broadcasters. Many of the professionals broadcast on the same wavelength and either came to a gentlemen's agreement to divide the hours of broadcasting or blithely set about cutting one another's throats by broadcasting simultaneously. Listeners thus experienced the annoyance of trying to hear one program against the raucous background of another.⁶

The market could not function properly because no one owned the resources involved—the individual wave-

lengths. The “chaos” could have been avoided by creating legally enforceable property rights in wavelengths and letting the market determine who would use the various frequencies.

The Federal Radio Commission (FRC) was established in 1927 to assign and enforce property rights in frequencies. It was succeeded by the Federal Communications Commission (FCC) in 1934. Eventually, the two agencies ended up taking a more active role in regulating the broadcast spectrum than advocated by most economists. For example, instead of assigning and enforcing property rights to the spectrum based on the willingness of various broadcasters to pay for it, the regulatory agencies set aside specified amounts of bandwidth for various types of uses (that is, a certain amount of bandwidth for radio broadcasting, VHF television broadcasting, UHF television broadcasting, and eventually services such as cellular telephones). Moreover, license awards and the approval of license sales came to be based on the extent to which broadcasters were deemed by the government regulatory agencies to serve the “public interest” rather than just economic efficiency.

⁶Ronald H. Coase, “The Federal Communications Commission,” *Journal of Law and Economics*, 2 No. 2 (October 1959), pp. 1–40.

APPLICATION 20.7**“O GIVE ME PROPERTY RIGHTS . . .”**

The importance of well-defined and legally enforceable property rights as a mechanism to avoid externalities is illustrated by the different fates of buffalo and cow herds in the late 1800s. In the case of the buffalo, property rights were not well defined and legally enforceable. They were, however, in the case of cow herds. The result was predictable and has been recounted in the following poem by Nobel Prize-winning economist, Ken Boulding:

“Ode to Property Rights”

The buffalo, nobody's property
Went o'er the plains, clippity cloppity
In thunderous herds, where now only birds
Fly and rabbits go hippity, hoppity.

The cow, now, is kept on the farm
And flourished and came to no harm
For its owners to thrive
Had to keep it alive
So property worked like a charm.

The Coase Theorem

These examples suggest that the assignment of property rights can make an important contribution to resolving issues involving externalities—but who is to have exactly what right to use the resource in question? Should a factory have the right to discharge smoke into the atmosphere, or should a nearby resident have the right to pure air? A case can certainly be made that both of these parties have a reasonable claim to use the atmosphere for their own purposes, yet giving the resident the right to clean air denies the factory the right to use a smokestack, and vice versa.

Ronald Coase addressed this issue in one of the most widely read papers in the history of economics.⁷ Coase developed his analysis by considering a rancher and a farmer with adjoining properties. The rancher's cattle occasionally stray onto the farmer's property and destroy some of the crops—an external cost associated with cattle raising if this cost is not properly taken into account. Now suppose the farmer has the right to grow crops in a trample-free environment. The rancher would then be legally liable for the damage caused by the straying cattle. Since the rancher will have to compensate the farmer for the crop damage, the cost of straying cattle will become a direct cost to the rancher and will be taken into account in the rancher's production decision. An efficient outcome will result, probably one involving fewer straying cattle.

This conclusion is familiar, but Coase went further and argued that even if the rancher were not liable for damages, an efficient outcome would still result! This situation corresponds to giving the rancher the right to allow his or her cattle to stray. Coase explained that the farmer then has an incentive to offer to pay the rancher to reduce the number of straying cattle because a reduction in crop damage increases the farmer's profit. The harm done by straying cattle necessarily implies that the farmer will be willing to pay something to avoid that harm. An agreement would therefore be struck that would reduce cattle straying to the efficient level.

As far as efficiency is concerned, the **Coase theorem** states that whether the farmer or the rancher is initially assigned the property rights doesn't matter. *As long as the rights are clearly defined and enforced, bargaining between the parties can ensure an efficient outcome.* The distributional effects, though, depend on the exact definition of property rights. If the rancher is liable, the rancher will compensate the farmer; alternatively, if the rancher is not liable, the farmer will pay the rancher to reduce the cattle straying. In both cases cattle straying and crop damage are reduced to the efficient level, but different people bear the cost and secure the benefit.

Simply assigning property rights, however, will not resolve all externality problems. In the case discussed earlier, a firm pollutes a river and many people living downstream are harmed. If downstream residents are given the right to have clean river water, would bargaining between parties lead to an efficient level of water pollution? Most likely not. This is because thousands of people are affected by the pollution, and a firm would have to negotiate an agreement with all of them simultaneously to be allowed to pollute. *Whenever the effects are nonrival over a large group and exclusion is not feasible, the free-rider problem hinders the process of achieving agreement among all concerned.* The negotiation process likely would be so costly and time consuming as to become a practical impossibility. Consequently, with such an assignment of property rights, there would be no pollution in the river—but that may be as inefficient as (or perhaps even more inefficient than) allowing the firm to pollute freely.

Our earlier conclusion that markets would be inefficient is correct, therefore, in the case where the external effects simultaneously fall on many people. Assigning property rights can solve externality problems when there are small numbers of parties involved but not as readily when there are large numbers, because of the free-rider problem. Many issues of great importance, such as defense, pollution, and police protection, are large-group externalities or

COASE THEOREM

the idea that as long as property rights are clearly defined and enforced, bargaining between two parties can ensure an efficient outcome

⁷Ronald H. Coase, "The Problem of Social Cost," *Journal of Law and Economics*, 3 No. 2 (October 1960), pp. 1–45.

public goods, and private markets are thus unlikely to function effectively in these areas without some form of government intervention.

20.5

CONTROLLING POLLUTION, REVISITED

Perfect competition ensures efficiency in industry output if demand and supply curve heights reflect the full marginal benefits and costs associated with a particular product. There are cases, however, where assuming that demand and supply curve heights reflect a product's full marginal benefits and costs is not valid. Oil refineries, for example, may not be fully accountable for the costs associated with their productive activities. The refineries, that is, may not have to pay for the air pollution caused by their operations and imposed on surrounding communities.

As we saw earlier in this chapter, when demand and supply curve heights do not reflect a product's full marginal benefits and costs, the industry output attained by perfect competition is generally not efficient. Still, even if an industry does not attain efficiency in output because certain benefits and costs are external to the decisionmaking of consumers and firms, perfect competition results in efficiency in production. The industry output that is produced, in other words, is produced at lowest possible cost even though it may not be the efficient output.

To see how competition ensures production efficiency even if output efficiency is not attained, reconsider the case of two oil refineries first introduced in Chapter 8. Refineries A and B are located in the Los Angeles basin. Suppose they impose air pollution costs that they do not have to pay for on their surrounding communities. As a result, the firms' individual output decisions are based on only part of the costs associated with their productive activities and (as we saw in Section 20.3) the realized industry output is not efficient.

Policymakers may seek to ensure that the refineries account for the costs of their air pollution by levying a tax per unit of air pollution emitted. The tax creates an incentive for each refinery to curtail pollution, because the refinery saves the amount of the tax per unit of pollution not emitted. If reducing pollution by one unit costs the refinery less than the tax, the refinery has an incentive to engage in pollution abatement.

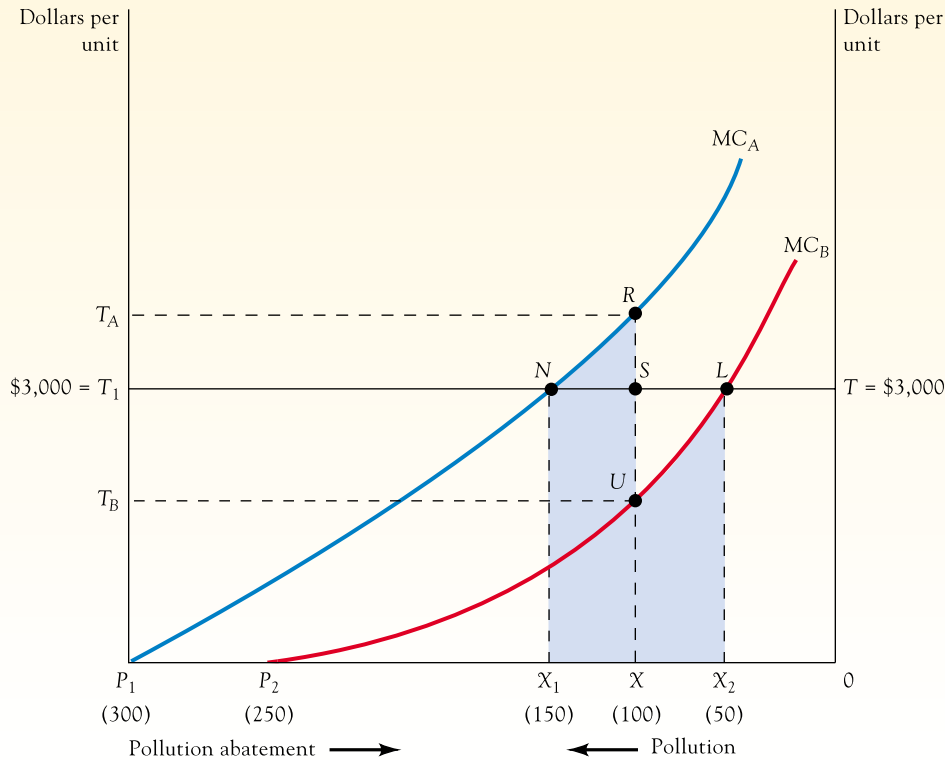
The appropriate tax policymakers should levy per pollution unit to ensure output efficiency may, of course, be difficult to determine. Regardless of the amount of the tax, however, the total amount of pollution abatement across all refineries in response to the tax will be produced at lowest possible cost (will achieve efficiency in production) if perfect competition prevails.

Say that a tax of \$3,000 per unit of air pollution emitted is imposed on refinery A. Figure 20.4 shows how such a tax would affect the level of air pollution. As in Chapter 8, pollution is measured from right to left, and the refineries' marginal cost curves for pollution abatement are shown as MC_A and MC_B . (Ignore refinery B for the moment.) A tax of \$3,000 per unit of pollution can be shown as a horizontal line at \$3,000. A refinery's total tax liability is \$3,000 times the number of units of air pollution. If refinery A continues to pollute at its initial level, OP_1 (when there was no pollution tax), it will have to pay a tax equal to OT (\$3,000) times OP_1 , which is the area OTT_1P_1 .

The tax gives refinery A an incentive to curtail pollution, because each abatement unit saves \$3,000 in taxes. Looked at from left to right, the horizontal line T_1T is like a demand curve for pollution abatement: It shows a gain in net revenue of \$3,000 per unit of abatement produced. Thus, refinery A faces a horizontal demand curve for abatement, and its marginal cost curve indicates the cost of abatement. To maximize profit, the refinery has a strong incentive to curtail pollution. Specifically, if the refinery can eliminate a unit of pollution for less than \$3,000, doing so adds more to net revenue (reducing taxes by \$3,000) than it adds

FIGURE 20.4**A Tax on Pollution**

A per-unit tax on pollution makes refineries competitive producers of pollution abatement. With a tax of \$3,000 per unit of pollution, refinery A produces P_1X_1 abatement units (OX_1 pollution units), and refinery B produces P_2X_2 abatement units (OX_2 pollution units).



to cost. In the interest of profit, refinery A will curtail pollution to OX_1 (producing P_1X_1 in abatement), where the marginal cost of abatement exactly equals the \$3,000 per-unit tax. Cutting back further is not worthwhile because the cost of more abatement exceeds the tax saving. With pollution of OX_1 refinery A still pays total taxes of $OTNX_1$, but this sum is significantly less than the tax cost associated with the initial pollution level OP_1 .⁸

Now let's turn to refinery B. The same analysis is relevant for refinery B, which has an incentive to cut back pollution to OX_2 , where its marginal cost of abatement equals the \$3,000 per-unit tax. Note what this means: refinery A and refinery B are both operating at an abatement level where marginal cost equals \$3,000. Their marginal costs are the same, which implies that the total amount of abatement of 350 units ($P_1X_1 = 300 - 150 = 150$ units by refinery A plus $P_2X_2 = 250 - 50 = 200$ units by refinery B) is achieved in the least costly way. And this outcome happens without the government's knowing either refinery's marginal cost curve. By applying the same tax to both refineries, the government gives each re-

⁸This analysis does not show how the pollution tax affects the refinery in its product market. Of course, the tax increases production cost and shifts the cost curves upward. To be accurate here, we should explicitly assume that the tax is not so large that it becomes unprofitable for the refinery to stay in business.

finery the same incentive to curtail pollution. The result is efficient coordination of their independent production decisions.

To better understand why the total cost of achieving 350 abatement units is minimized by relying on incentives and competitive market forces, consider a reallocation of abatement units among the two refineries. For example, consider what happens if refinery A produces 50 additional units and refinery B produces 50 fewer units (so combined output remains unchanged). Refinery A's production cost goes up by the sum of the marginal cost of each unit from 151 to 200, shown by area X_1NRX . Refinery B's production cost falls by the sum of the marginal cost of each unit it ceases to produce, shown by area $XULX_2$. Because refinery A's cost increase exceeds refinery B's cost saving (as can be seen in Figure 20.4 by recalling that the widths of the shaded areas are equal), the total cost of producing 350 abatement units is higher under such a reallocation. Similar reasoning shows that any other way of having the refineries produce a total of 350 abatement units results in a higher total production cost than that achieved by the competitive refineries individually choosing their profit-maximizing outputs.

The foregoing discussion indicates why many economists favor taxation as a pollution control strategy. Notwithstanding the difficulty of determining the "appropriate" level of the tax that will result in efficiency in output (a tax that equals the marginal external costs associated with pollution), a pollution tax effectively creates market incentives for firms to reduce pollution in the least costly manner and thereby ensures efficiency in production. Moreover, the size of the tax can be changed to regulate the amount of pollution: a larger tax per unit will reduce pollution further.

In the United States, most environmental policies rely on a command-and-control approach: regulations and quantity limitations rather than taxes. Many economists have been critical of these non-market-oriented policies, in part because they believe the taxation approach can achieve the same results at lower cost. And the taxation approach is more than a theorist's pipe dream. Germany, for example, has successfully used pollution taxes to regulate waste discharge into the Ruhr River for over 50 years.

The Market for Los Angeles Smog

An alternative market-oriented approach to controlling pollution involves the setting of an overall industry pollution level, with each firm receiving permits to emit a certain amount of pollution units and allowing firms to exchange their permits. This Coasean approach has recently been adopted by policymakers in an attempt to control smog in the Los Angeles basin. Tradable permits to pollute have been issued to each of the 390 companies producing four or more tons of emissions annually. The overall emission level allowed through the permits is set below the existing level and will be further reduced each year so that by the year 2004, nitrogen oxides are cut by 75 percent and sulfur oxides by 60 percent. Pollution permits are allocated across firms more or less according to their existing emissions.

The recently established L.A. smog market allows an overall emission target to be achieved in the least costly manner. To see why, suppose that in our simple example the goal is to reduce air pollution by 350 units (the same reduction achieved by a tax of \$3,000 per emission unit) and that the two refineries are issued tradable permits to emit 100 pollution units each (200 total units across the two refineries). As shown in Figure 20.4, with no pollution control whatsoever, 550 pollution units would be produced—300 by refinery A (OP_1) and 250 by refinery B (OP_2).

Under the tradable-permit scheme, the potential exists for mutual gains from trade between the two refineries. This is because at its allotted 100 emission units, refinery A's marginal abatement cost (T_A) exceeds refinery B's abatement cost (T_B). Since, at the margin, refinery A is willing to pay more to increase its emission (cutting its abatement costs T_A) than refinery B needs to be paid to decrease its emission (incurring abatement costs T_B),

there is room for the two refineries to exchange pollution permits for a price somewhere between T_A and T_B , making both sides better off.

Of course, the exact price at which the permits will be exchanged will depend on, among other things, the bargaining abilities of the two refineries. Moreover, the bounds around the exchange price will narrow as more permits are sold by refinery B to refinery A. The bounds around the exchange price will narrow because as refinery A buys more permits, the maximum amount it is willing to pay per permit declines from T_A ; the cost of abatement to refinery A decreases as it pollutes more and moves to the left along its marginal cost of abatement curve. In addition, as refinery B sells additional permits, the minimum amount it needs to be paid for each rises from T_B ; the cost of abatement to refinery B rises as it pollutes less and moves right along its marginal cost curve.

How many permits will be exchanged? The total will be 50 in the case depicted in Figure 20.4. When refinery B sells this many permits to refinery A, their marginal costs of abatement are identical. Refinery B, because it has the lower marginal cost of abatement curve, ends up emitting OX_2 (50) pollution units, abating P_2X_2 ($250 - 50 = 200$) units, and having a marginal cost of abatement of T_1 . Refinery A ends up emitting OX_1 (150) pollution units, abating P_1X_1 ($300 - 150 = 150$) units, and having a marginal cost of abatement of T_1 . The price for the fiftieth exchanged pollution permit equals \$3,000 since it is perfectly constricted by the two refineries' marginal costs of abatement (that is, T_1).

By generating the "proper" marginal permit price ("proper" in terms of achieving an overall level of 200 pollution units and 350 units of pollution abatement) and confronting both refineries with that price, the L.A. smog market ensures attainment of the overall emission target in the least costly way. If, instead of allowing permit trading, regulators limited each refinery to 100 pollution units, the total abatement cost would be higher. That efficiency in production would not be served through such a command-and-control device is evidenced by the fact that in Figure 20.4 the cost to refinery A of reducing its pollution from 150 to 100 units (area X_1NRX) exceeds the cost to refinery B of reducing its pollution from 100 to 50 units (area $XULX_2$). The same overall emission target of 200 units can thus be achieved at lower total cost if refinery A is allowed to emit 150 units and refinery B is permitted 50 units.

In sum, market-based pollution control mechanisms such as tradable emission permits or per-emission-unit taxes promote efficiency in production. Although such mechanisms do not necessarily guarantee the attainment of output efficiency, they do ensure that any abatement amount produced by an industry is produced at lowest possible cost.

The cost savings associated with market-based pollution control mechanisms can be substantial in the real world. For example, economists have estimated that the L.A. smog market saves \$1,000 per year in abatement costs per resident household relative to a policy of mandating proportional, across-the-board reductions in emissions and not allowing pollution permit trading.⁹ Significant abatement cost savings could also be realized if emission trading programs were more broadly implemented on a national as well as international basis. For example, according to the consulting firm Charles River Associates, the cost for reducing greenhouse-gas emissions according to the Kyoto Protocol (a greenhouse-gas reduction treaty signed in 1997 as part of the United Nations Framework Convention on Climate Change) is estimated to be \$280 per ton if no trading in emissions permits is allowed. By contrast, the estimated cost drops to \$60 per ton if a completely open market in emissions permits is authorized.¹⁰

⁹David Harrison, Jr. and Albert L. Nichols, *Market-Based Approaches to Reduce the Cost of Clean Air in California's South Coast Basin* (Cambridge, Mass.: National Economic Research Associates, November 1990).

¹⁰"Letting the Free Market Clear the Air," *Business Week*, November 6, 2000, pp. 200–204.

Among some of the other market-oriented pollution control mechanisms with which policymakers have experimented over the past three decades are “bubbles,” through which a firm can treat an existing plant with multiple emission sources as if it were a single source—a bubble allows a firm to adjust its various emission sources to meet an overall emission target for the plant in the least costly manner; banking of pollution abatement credits, whereby a firm can hold onto emission reduction credits for future use or sale; and offsetting—a major new emission source in regions failing to meet national air quality standards can compensate for its added pollution with emission reductions of an equal or greater amount achieved through internal or external trades. All of these market-based approaches promise significant efficiencies in production over the more commonly employed command-and-control mechanisms for dealing with pollution.



SUMMARY

- Public goods are characterized by nonrival consumption and nonexclusion. When a good has these two characteristics, the free-rider problem arises and makes it difficult to ensure that the efficient quantity will be produced through voluntary arrangements.
- An efficient output of a public good is that at which the vertically summed demand curves of individuals intersect the marginal cost, or supply, curve.
- Externalities are the harmful or beneficial side effects of market activities that are borne or realized by people not directly involved in the market exchanges. They represent costs or benefits that are not incorporated in the private supply and demand curves that guide economic activity. Once again, the result is an inefficient resource allocation.
- In some cases it is only necessary to define property rights appropriately for externalities to be taken into account. In other cases, principally those involving large numbers of people, this solution will likely not work and other types of government policies should be considered.
- With regard to accounting for the externalities associated with air pollution, government policies that can promote efficiency in production include per-emission-unit taxes and tradable permits to emit a certain amount of pollution.



REVIEW QUESTIONS AND PROBLEMS

Questions and problems marked with an asterisk have solutions given in Answers to Selected Problems at the back of the book (pages 584–585).

- 20.1.** What two characteristics define a public good? Which of the following are public goods: parks, police services, welfare payments to the poor, production of energy, space exploration?
- 20.2.** Why will private markets produce an inefficient output of a public good? Explain how the efficient level of a public good is determined.
- 20.3.** What is meant by the “free-rider” problem? How does it relate to the provision of public goods? How can it be overcome?
- *20.4.** Suppose there are three consumers—two “hawks” and one “dove.” The dove receives negative benefits from (is harmed by) national defense, but the hawks value defense. Show graphically how an efficient output of defense is determined in this case.
- 20.5.** From a public good perspective, critique the use of patents.
- 20.6.** “External costs are bad, and government intervention to reduce them is justified. External benefits, however, are good, and there is no reason for government intervention in this case.” Evaluate these statements.
- 20.7.** Education is sometimes cited as a source of external benefits. In what way, if at all, does your receiving a college education benefit other people?
- *20.8.** Suppose that property rights change so that students no longer have exclusive rights to the use of lecture notes they take in classes. (All notes are collected after class, and anyone can borrow notes for 24 hours on a first-come, first-served basis.) How would this policy affect note taking, class attendance, and studying? Would students learn more or less? What does this example illustrate about the relationship between externalities and property rights?

20.9. A piece of state legislation proposes banning smoking in nearly all public facilities and private businesses. The major argument for the bill is that it “is needed to protect nonsmokers from the health hazards of cigarettes.” Prepare an evaluation of the economic case for this legislation. (Assume that smoking adversely affects the health of nearby nonsmokers.)

***20.10.** “When public goods or externalities lead to inefficient resource allocation, government intervention is justified.” Is it? Why?

20.11. In an otherwise competitive economy there is an externality in the form of pollution. Show what the private market equilibrium implies in terms of where we are on (or inside of) the welfare frontier.

20.12. In Figure 20.2, suppose the government placed a quota instead of a tax on the output of the product that limited output to a maximum of Q_E . Would this policy achieve an efficient allocation of resources?

20.13. In discussing Figure 20.3, the text states that the private equilibrium output, Q_1 , is inefficient. By definition, inefficiency is supposed to mean that everyone could be better off with a different allocation of resources. Does the subsidy shown in the diagram benefit everyone, including the taxpayer who pays to finance it? If not, what type of policy could be used that would benefit everyone?

20.14. A miracle drug that cures obesity is developed and produced competitively at a constant cost to producers of 10 cents per dose. The companies that produce the drug, however, discharge chemical wastes resulting from the production process into the nation’s rivers. The damage to the economy in terms of reduced commercial and recreational use of the waterways is estimated to be 1 cent per dose. The social demand for the drug is $Q = 1,000,000 - 10,000P$, where Q indicates the number of doses produced and P is the price per dose measured in cents.

- How much of the miracle drug is produced? At what price? Give both numerical and graphical answers.
- An economist testifies before Congress that obesity cures are being overproduced and sold too cheaply. What price and quantity do you think the economist would advocate? What is she likely to estimate as the cost to the economy of the supposed overproduction? Give numerical and graphical answers.
- The economist argues that a tax should be placed on every unit of output that is accompanied by a waste discharge. What size tax per unit of output would an efficiency-seeking economist advocate? With this tax, what would the price and output be for the miracle drug? Give both numerical and graphical answers.

20.15. Suppose that in the preceding problem drug producers invent another production process that discharges no waste and can be used at a constant cost of 10.6 cents per dose.

- What will the price and output of the miracle drug be if the tax advocated in part (c) of the preceding problem is imposed?

- What will the price and output be if the no-discharge process had a cost of 11.4 cents per dose?
- Suppose that the production cost under the new process rises to 13 cents per unit and producers are forbidden to use the original waste-discharging process. What price and output will result? By the economist’s criteria, are there appropriate amounts of obesity cures and pollution? What is the dead-weight loss, if any, that results? Give both numerical and graphical answers.

20.16. Comment on the following hypothetical remarks by the Congressional representatives who questioned the economist in Problem 20.14. Do you agree or disagree? (You don’t have to play the role of an economist in your answer.)

Senator Anthony: “No value can be placed on the benefit this drug brings to humanity.”

Senator Loeb: “The cure for obesity should be provided freely to all who need it.”

20.17. Distinguish between efficiency in production and efficiency in output. Can an industry achieve efficiency in production and still produce at an inefficient output level? Explain.

20.18. Explain why efficiency in production is not realized if both refineries in Figure 20.4 are limited to emitting 100 pollution units each.

20.19. A clothing factory is located downwind from a copper smelting plant. The copper smelting plant emits particulates into the air that cause \$100,000 in damage per year to the clothing factory in terms of fabric discoloration. The plant could eliminate its emissions of particulates by installing a superior scrubbing technology at a cost of \$50,000 per year. Existing regulations do not prohibit the emission of these particulates. The only way to remedy the inefficiency associated with the emissions is through government intervention. True or false? Explain your answer.

20.20. The defense services provided by submarines are a public good. Suppose that the equation relating the marginal benefit Ted derives from the quantity of submarines produced (Q) is $MB = 600 - 10Q$. The equation relating the marginal benefit Jane derives from submarines is $MB = 400 - 10Q$. The marginal cost of producing each submarine is a constant \$400.

- If Ted and Jane are the only two individuals who benefit from the defense services provided by submarines, what is the efficient output of submarines?
- Without any coordination between Ted and Jane and/or government intervention, what will be the output of submarines? Explain your answer. What will be the size of any resulting inefficiency?
- Suggest a taxing scheme to ensure the attainment of efficiency in the provision of submarines.
- Suppose that the defense services afforded by submarines are still nonrival in consumption but that the cost of excluding a demander is zero. If submarines are produced by a monopolist practicing third-degree price discrimination (that is, a pro-

ducer that charges different prices to different demanders), what will be the profit-maximizing output and price that the monopolist will charge Ted and Jane? How does your answer compare to that in part (a)?

20.21. Much public debate has focused on the external costs associated with smoking. Explain why there may also be an external benefit from smoking in that smokers die at an earlier age than nonsmokers.

20.22. The United Nations Kyoto Protocol of 1997 requires most industrial nations to reduce their carbon dioxide and other greenhouse-gas emissions during the ensuing decade to about 5 percent of 1990 levels. Explain why such a policy is inefficient.

20.23. As cellular or mobile phones proliferate rapidly, with more than 100 million U.S. users, so do complaints about cell phone rudeness. “No Cell Phones” signs are popping up all over. Restaurants, theaters, libraries, museums, and doctors’ offices have banned the devices. Explain why, using the concept of externalities.

20.24. As of the late 1990s, there had been instances of Russians shooting at Japanese, Tunisians shooting at Italians, and Portuguese shooting at Spaniards. This is just a partial list of the heated conflicts occurring on the high seas between aggressive fishing fleets and well-armed navy and coast guard vessels jealously protecting a lucrative and declining resource. At the source of the conflict appears to be the inability to define property rights to fish. Explain why.

20.25. The military alliance NATO (North Atlantic Treaty Organization) was formed during the Cold War to prevent military action against its member states by the former Soviet Union. During its heyday, the seven countries belonging to NATO with the largest gross national products (GNPs) spent

7.8 percent of their combined GNP on defense. The seven nations with the smallest GNPs spent only 4.3 percent. Provide an economic explanation for this phenomenon.

20.26. When film crews rent a house to shoot a scene for a movie, external costs may be imposed on neighboring households in the forms of occupied/blocked parking spaces, bright lights, and explosions. Relying on the Coase theorem, explain why neighbors have been known to go to some unusual lengths (revving up lawn mowers or stereos, turning on leaf blowers, blowing foghorns, and banging garbage pail lids against iron gates) in cases such as this, especially when filmmakers are about to start shooting a scene.

20.27. In 2002, some firms in the music industry began selling CDs designed to make it impossible for buyers to copy music from the CDs to their personal computers, exchange songs over the Internet, or transfer material from the CDs to portable MP3 players. Will the spread of such copy-protection technology promote efficiency? Explain why or why not.

20.28. Because the federal government covered the lion’s share of the costs, Los Angeles built the 17.4-mile-long Red Line subway system in the 1990s at a cost of \$4.7 billion (\$270 million per mile). The fully allocated costs are estimated to be \$1.15 per passenger mile, whereas the fare is \$0.07 per mile for the 17.4-mile-long Red Line journey. Using a graph, explain why output efficiency was or was not served by the subway’s construction. (*Note:* to cover the city’s portion of the construction costs, local bus fares were raised, and daily bus ridership declined by more in the wake of the fare increase than the number of residents taking the Red Line on an average day.)

20.29. Should entrance fees be charged at our nation’s parks? Explain why or why not?

