17 Externalities and Public Goods

When Does the Invisible Hand Fail?

Economist Herbert Mohring has described a situation familiar to all of us: "The users of road and other transportation networks not only experience congestion, they create it. In deciding how and when to travel, most travelers take into account the congestion they expect to experience; few consider the costs their trips impose on others by adding to congestion."[1] This scenario involves an externality that arises because each driver bears only part of the costs that he or she imposes on society when making a trip. To see why, note that, as a driver on the highway, your costs (i.e., the price of driving) include gas and oil, wear and tear on your car, and any tolls, as well as the cost of your time spent driving (you could have spent that time doing something productive). These are the costs you are likely to take into account when deciding whether to drive, but there are other costs that you are much less likely to consider because you do not bear them yourself—for instance, adding to traffic congestion and thereby increasing the travel time (and associated cost) for other drivers. The costs that you as a driver impose on society include both these kinds of costs—the ones you bear yourself (*internal* costs) and the ones borne by others (*external* costs).

[1]See H. Mohring, "Congestion," Chapter 6 in *Essays in Transportation Economics and Policy: A Handbook in Honor of John R. Meyer*; J. Gomez-Ibanez, W. Tye, and C. Winston, eds. (Washington, DC: Brookings Institution Press, 1999).

External costs (or benefits) can be significant, as Mohring saw when studying the effects of rush hour congestion in Minneapolis and St. Paul, Minnesota, using data on travel patterns in 1990. He found that "the average peak-hour trip imposes costs on other travelers equal to roughly half of the cost directly experienced by those taking the average trip."

A public good benefits all consumers, even though individual consumers may not pay for the costs of its provision. Examples include national defense, public radio and television, and public parks. A public good has two features: (1) consumption of the good by one person does not reduce the amount that another can consume, and (2) a consumer cannot be excluded from access to the good. For example, anyone can view a public television station, and the reception of the signal by one person does not reduce the opportunity for others to receive it.

Why worry about externalities and public goods? As we will see in this chapter, with an externality or a public good, the costs and benefits affecting some decision makers differ from those for society as a whole, causing the market to undersupply public goods and creating situations where social costs differ from social benefits. Thus, in a competitive market when there are externalities or public goods, the *invisible hand* may not guide the market to an economically efficient allocation of resources.

CHAPTER PREVIEW After reading and studying this chapter, you will be able to:

- Define externalities and public goods.
- Explain why externalities and public goods are a source of market failure.
- Distinguish between positive and negative externalities.
- Analyze how taxes, emissions fees, emissions standards, or emissions trading markets could reduce the economic inefficiency that arises in a competitive market with a negative externality.
- Analyze how a congestion toll can reduce the economic inefficiency due to negative externalities from traffic congestion.
- Explain how a subsidy could reduce the economic inefficiency that arises in a competitive market with a positive externality.
- Describe the Coase Theorem and discuss its economic significance.
- Show how the efficient quantity of a public good is determined.
- Explain the free rider problem.

17.1 INTRODUCTION

Markets with externalities and markets with public goods are two kinds of markets that are unlikely to allocate resources efficiently. We first encountered externalities in Chapter 5, where we studied network externalities. In general, the defining feature of an **externality** is that the actions of one consumer or producer affect other consumers' or producers' costs or benefits in a way not fully reflected by market prices (in our chapter-opening example, for instance, the individual driver's price for driving on the highway doesn't reflect the social cost of increased congestion). A **public good**, in general, has two defining features: first, one person's consumption of the good (e.g., driving x miles on the highway) does not reduce the quantity that can be consumed by any other person (all other drivers can still drive as far as they want on the highway); and second, all consumers have access to the good (any driver can drive on the highway).

externality The effect that an action of any decision maker has on the well-being of other consumers or producers, beyond the effects transmitted by changes in prices.

public good A good, such as national defense, that has two defining features: first, one person's consumption does not reduce the quantity that can be consumed by any other person; second, all consumers have access to the good.

Public goods include such services as national defense, public parks and highways, and public radio and television. To see why public television, for example, is a public good, note how it conforms to the definition above: when one viewer watches a public television program, no other viewer is prevented from watching it (to put this another way, the marginal cost of serving an additional viewer is zero); further, once the television program is broadcast, no viewer can be excluded from watching it.

In Chapter 10, we used partial equilibrium analysis to show that a competitive market maximizes the sum of consumer and producer surplus. Since there are no externalities or public goods in a perfectly competitive market, the private costs and benefits that decision makers face are the same as the social costs and benefits. In this case, the invisible hand guides the market to produce the efficient level of output, even though each producer and consumer acts solely in his or her own self-interest. In Chapter 16, we extended the analysis of competitive markets to a general equilibrium setting and showed that the allocation of resources in a competitive equilibrium is economically efficient (again assuming an absence of externalities and public goods).

When the market includes externalities or public goods, however, the market price may not reflect the social value of the good, and the market may therefore not maximize total surplus—that is, the equilibrium may be economically inefficient. For this reason, externalities and public goods are often identified as sources of *market failure*.

APPLICATION 17.1

How to Avoid "Collapse" of a Fish Species

Since at least the 1970s, scientists have continued to warn that many fish species are in danger of being "overfished" due to increased human consumption. Overfishing could ultimately lead to the irreparable harm or even extinction of a species. For example, a dramatic decline in Atlantic cod populations in the early 1990s led the Canadian government to impose an indefinite moratorium on cod fishing in the Grand Banks, an area off the coast of Newfoundland with one of the richest fishing areas on the planet. In 2006 the Fisheries Service of the National Oceanic and Atmospheric Administration estimated 20 percent of U.S. fisheries to be overfished.[2] At the same time a study in *Nature* in 2006 estimated that 29 percent of species studied had declined to 10 percent of their original levels, what they term a "collapse" of a species. The primary cause was overfishing, though pollution and loss of habitat are also factors.

In 2008, a study in *Science* provided some hope for the problem of overfishing.[3] Scientists studied more than 11,000 fisheries worldwide to try to find a system that would avoid overfishing. They concluded

[2]Cornelia Dean, "Study Sees 'Global Collapse' of Fish Species," *New York Times*, November 3, 2006.
[3]John Tierney, "How to Save Fish," *New York Times*, September 18, 2008.

that a system called "catch shares" holds promise. In the catch shares system, a maximum allowable catch is determined each year by the government with input from fishery scientists. Specific fishermen own the rights to a certain percentage of the annual quota, and only those with such rights are allowed to catch that type of fish. The quota rights can be bought and sold at the current market price. If the fish population thrives, the rights have more value. If the fish are overfished, the rights go down in value. This gives incentives to the fishermen to protect the species from overfishing. For example, after a catch shares system was implemented in Alaska, fishermen began using fewer hooks, resulting in less harm to the fish population, since they no longer had to "race to fish" in competition with each other. Of course, limiting the maximum catch per year also helps solve the overfishing problem.

In the *Science* study, researchers found that fisheries using a catch shares system had only half the odds of a species collapse. Moreover, the fish population became stronger the longer the catch shares system had been used. In some fisheries that use catch shares, the fishing industry has actually lobbied to impose even stricter limits than those suggested by biologists, in order to further improve the economic value of the fishery.

Fishing grounds are an example of a common property resource, and the fishing done by one fisherman imposes a negative externality on other fisherman. This gives rise to a market failure. In this chapter, you will learn how negative externalities can lead to market failure, and you will study possible government interventions that can offset or eliminate the inefficiency that the market failure gives rise to. You will find that there may be solutions to externality problems that largely play out in a private market. A catch shares system is one such example.

Currently, about 1 percent of fisheries worldwide use this system. Despite such promising results, the catch shares system is still controversial. Some environmental groups oppose the system, though others have become advocates given recent evidence on their effectiveness. If a catch shares system helps overcome inefficiencies due to a market failure, we would expect it to catch on and become more widely used. It will be interesting to see if, over the next decade, this happens.

17.2 EXTERNALITIES

Externalities can arise in many ways, but, however they arise, their effects are always the same: The actions of a consumer or producer may benefit or harm other consumers or producers.

Externalities are *positive* if they help other producers or consumers. We frequently observe positive externalities from consumption. For example, when a child is vaccinated to prevent the spread of a contagious disease, that child receives a private benefit because the immunization protects her from contracting the disease. Further, because she is less likely to transmit the disease, other children in the community benefit as well. The *bandwagon effect* we studied in Chapter 5 is a positive externality because one consumer's decision to buy a good improves the well-being of other consumers.

There are also many examples of positive externalities from production. The development of a new technology like the laser or the transistor often benefits not only the inventor, but also many other producers and consumers in the economy.

Externalities can also be *negative* if they impose costs on or reduce benefits for other producers or consumers. For example, a negative externality from production occurs if a manufacturer of an industrial good causes environmental damage by polluting the air or water. A negative externality from consumption occurs if there is a *snob effect*, as we learned in Chapter 5.

Highway congestion, as discussed in the introduction to this chapter, is also an example of a negative externality. You are no doubt also familiar with other examples of congestion externalities, including those encountered on computer networks, in telephone systems, and in air transportation.

How important are negative externalities in a modern economy? The short answer is: quite important. Consider, for example, the research of economists Nicholas Muller, Robert Mendelsohn, and William Nordhaus, who studied the costs of negative environmental externalities to the U.S. economy for six major air pollutants: sulfur dioxide, nitrogen oxides, volatile organic compounds, ammonia, fine particulate matter, and coarse particulate matter.[4] The social costs of air pollution from these compounds—what Muller, Mendelsohn, and Nordhaus call *gross external damages* (GED)—include negative effects on human health, social costs of reduced visibility, reductions in agricultural and timber yields, and degradation of recreational areas.

APPLICATION 17.2

Gone Surfing?

If you have ever surfed the Internet, you have no doubt encountered an electronic experience similar to driving on a freeway. Often you are moving quickly from one Web page to another, while at other times you feel as though you are in stop-and-go traffic, waiting for a reply or slowly transmitting or downloading data. Everyone who sends an e-mail or downloads a file shares bandwidth, that is, the capacity for carrying data over the network. Sometimes, the capacity is adequate to handle the load without congestion. At other times, there is so much traffic that the network becomes congested, and additional messages further slow the flow of traffic.

Often described as an *information superhighway,* the Internet is a very large network connecting millions of computers around the world. Some of the larger connections serve as electronic pipelines, and the largest pipelines are known collectively as the *Internet backbone*. The backbone is a collection of networks run by major Internet service providers (ISPs), governments, and universities. These networks connect with each other at Internet exchange points (IXPs), allowing computers to connect with each other globally. There are currently 160 IXPs throughout the world, and 32 in the United States.

When you connect to the Internet, you incur private costs, including costs from network congestion because your time is valuable. You may also pay

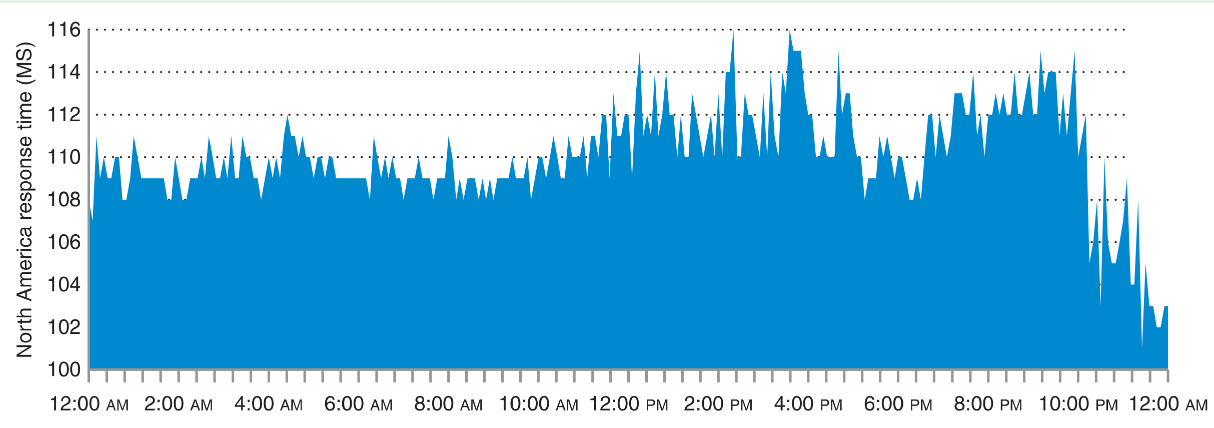


FIGURE 17.1 Congestion in the Internet
The speed with which traffic moves through the Internet varies during the day, depending on the amount of congestion in the network. The graph shows the speed of data flow in North America over January 29, 2013. The "response time" measures how long it takes for a set of data to travel from point A to point B and back (round trip). The response time is measured in milliseconds (thousands of a second). A response time of 100 ms means that it takes 1/10th of one second for the data to complete a round trip.
Source: Internet Traffic Report (www.internettrafficreport.com/namerica.htm), January 30, 2013.

[4]"Environmental Accounting for Pollution in the United States Economy," *American Economic Review*, Vol. 101, (August 2011), pp. 1649–1675.

charges for each minute you are connected to the network. If your benefits from connecting exceed these private costs, you will stay online. If your private costs are too high because of congestion, you may decide to delay going online until another time.

Many users consult websites that provide current information on the extent of congestion on the Internet, much as they listen to traffic reports on radio or television stations before deciding whether to make a trip by auto. For example, the Internet Traffic Report (http://www.internettrafficreport.com) measures the round-trip travel time for messages sent along major paths of the Internet. For a typical day, January 29, 2013, Figure 17.1 shows that the Internet in North America was relatively congested between about 6:00 P.M. and 10:00 P.M. Mountain Standard Time, and much less congested in the early hours of the morning. This interesting site also reports response times in Asia, Australia, Europe, and South America.

You may also impose external costs on other users when you surf the Web because your own traffic adds to congestion throughout the network. Like the automobile commuter, while you think about the private (internal) costs that you incur because of congestion, you probably do *not* think about the external costs you impose on others as your own traffic adds to congestion.

Overall, the total GED for the U.S. economy in 2002 was estimated to be $184 billion (expressed in 2000 dollars). This was about 1.5 percent of GDP in that year. This relatively small percentage disguises the significant levels of GED generated by certain sectors and industries. For example, the GED for the agriculture and forestry sector of the U.S. economy was estimated to be 38 percent of the sector's value added.[5] For the utility sector (which includes, among other things, electric power generation), GED was 34 percent of industry value added.[6] For a number of specific industries, such as coal-fired electric power generation, stone mining, and quarrying, the ratio of GED to value added was greater than one, indicating that the costs associated with air pollution externalities in these industries actually exceeded the industry's contribution to GDP.

Externalities can occur in a variety of market settings, including not only markets with competition, but also those with monopoly and other imperfect markets discussed in earlier chapters. In this chapter we will focus on the effects of externalities in otherwise competitive markets. As you read the chapter, you might think about how you can apply the principles we introduce to study the effects of externalities in markets that are not competitive.

NEGATIVE EXTERNALITIES AND ECONOMIC EFFICIENCY

Why do firms produce too much in an otherwise competitive market when there are negative externalities? Consider what happens when the production process for a chemical product also generates toxic emissions that harm the environment. Let's assume that only one technology is available to produce the chemical. That technology produces the chemical and the pollutant in fixed proportion: One unit of pollutant is emitted along with each ton of the chemical produced. Each producer of the chemical is "small" in the market, so each producer acts as a price taker.

If the producers do not have to pay for the environmental damage their pollution causes, each firm's private cost will be less than the social cost of producing the chemical. The private cost will include the costs of capital, labor, raw materials, and energy necessary to produce the chemical. However, the private cost will *not* include the cost of

[5]Value added equals an industry's sales minus its costs of purchased inputs. An industry's value added represents its contribution to GDP.

[6]For the electric power industry, the estimates of environmental damage also include the social cost of carbon emissions.

the damage that the toxic waste does to the air or water around the plant. The social cost includes both the private cost and the external cost of environmental damage.

Figure 17.2 illustrates the consequences of the externality in a competitive market. With a negative externality, the marginal social cost exceeds the marginal private cost. The marginal private cost curve *MPC* measures the industry's marginal cost of producing the chemical. Because the technology produces the pollutant and the chemical in a fixed proportion, the horizontal axis measures both the number of units of the pollutant and the number of tons of chemical produced. The marginal external

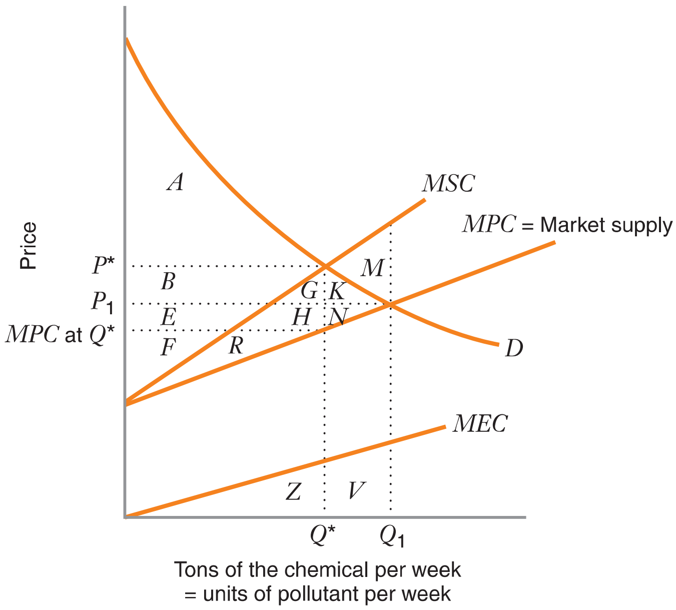


FIGURE 17.2 Negative Externality
With a negative externality, the marginal social cost *MSC* exceeds the marginal private cost *MPC* by the amount of the marginal external cost *MEC.* If firms do not pay for the external costs, the market supply curve is the marginal private cost of the industry *MPC.* The equilibrium price will be P_1, and the market output will be Q_1. At the social optimum, firms would be required to pay for the external costs, leading to a market price P^* and quantity Q^*. The externality therefore leads to overproduction in the market by the amount $(Q_1 - Q^*)$ and to a deadweight loss equal to area *M.*

	Equilibrium (price = P_1)	**Social Optimum (price = P^*)**	**Difference between Social Optimum and Equilibrium**
Consumer surplus	$A + B + G + K$	A	$-B - G - K$
Private producer surplus	$E + F + R + H + N$	$B + E + F + R + H + G$	$B + G - N$
−Cost of externality	$-R - H - N - G - K - M$	$-R - H - G$	$M + N + K$ (external cost savings)
Net social benefits (consumer surplus + private producer surplus − cost of externality)	$A + B + E + F - M$	$A + B + E + F$	M (increase in net benefits at social optimum)
Deadweight loss	M	Zero	M

cost of the pollutant is measured by *MEC*, which rises because the incremental damage to the environment increases as more pollution occurs. The marginal social cost *MSC* exceeds the marginal private cost by the amount of the marginal external cost: $MSC = MPC + MEC$. That is, the marginal social cost curve is the vertical sum of the marginal private cost curve and the marginal external cost curve.

If firms do not pay for the external costs, the market supply curve is the marginal private cost curve for the industry (the horizontal sum of the individual firms' marginal private cost curves). The equilibrium price will be P_1, and the market output will be Q_1.

The first column of the table in Figure 17.2 shows the net economic benefits in equilibrium with the negative externality. Consumer surplus is areas $A + B + G + K$—that is, the area below the market demand curve *D* and above the equilibrium price P_1. The private producer surplus is areas $E + F + R + H + N$ (the area below the market price and above the market supply curve). The cost of the externality is areas $R + H + N + G + K + M$ (the area below the marginal social cost curve and above the market supply curve), which is equal to areas $Z + V$. The net social benefits equal the sum of the consumer surplus and the private producer surplus, *minus* the cost of the externality—that is, areas $A + B + E + F - M$.

Now let's see why the competitive market fails to produce efficiently. In equilibrium the marginal benefit of the last unit produced is P_1, which is *lower* than the marginal social cost of production for that unit. Thus, the net economic benefit from producing that unit is negative.

The efficient amount of output in the market is Q^*, the quantity at which the market demand curve and the marginal social cost curve intersect. There the marginal benefit of the last unit produced (P^*) just equals the marginal social cost. The production of any units beyond Q^* creates a deadweight loss because the marginal social cost curve lies above the demand curve.

As shown in the second column of the table in Figure 17.2, if consumers pay the price P^* for the chemical, net economic benefits would increase. Consumer surplus would fall to *A* (the area under the demand curve and above P^*). Private producer surplus would be areas $B + E + F + R + H + G$ (the area below the price P^* and above the market supply curve). The external cost is areas $R + H + G$ (the area below the marginal social cost curve and above the market supply curve). The net social benefits equal consumer surplus plus private producer surplus *minus* the external cost ($-R - H - G$)—that is, areas $A + B + E + F$.

The third column of the table in Figure 17.2 shows the differences between the social optimum and the equilibrium in terms of consumer surplus, private producer surplus, and the cost of the externality. In terms of net social benefits, it also shows that the market failure arising from the externality creates a deadweight loss equal to area *M*.

To summarize, the negative externality leads the market to overproduce by the amount $Q_1 - Q^*$. It also reduces the net economic benefits by area *M*, the deadweight loss arising from the externality.

Learning-By-Doing Exercise 17.1 will help you understand why generally it is *not* socially optimal to prohibit industries from using technologies that produce negative externalities.

Emissions Standards

Figure 17.2 is useful in helping us understand why a market fails to produce efficiently with the negative externality. But what can be done to eliminate or reduce economic inefficiency? One possibility is for the government to intervene in the market by restricting the amount of the chemical that can be produced and, therefore, the amount of pollution emitted as a by-product. A governmental limit on the amount of pollution allowed is called an **emissions standard**.

emissions standard A governmental limit on the amount of pollution that may be emitted.

LEARNING-BY-DOING EXERCISE 17.1

The Efficient Amount of Pollution

Problem Evaluate the following argument: "Since pollution is a negative externality, it would be socially optimal to declare illegal the use of any production process that creates pollution."

Solution Refer to Figure 17.2. At the social optimum, net social benefits are areas $A + B + E + F$. While it is true that there are costs from the externality (areas $R + H + G$), the net social benefits from producing the chemical are nevertheless positive, even after taking the external costs into account. If it were illegal to produce the chemical because of the negative externality, society would be deprived of the net benefits represented by areas $A + B + E + F$. Thus, the optimal amount of pollution is not zero.

If we were to outlaw all pollution, we would deprive ourselves of many of the most important products and services in our lives, including gasoline and oil, electric power, many processed foods, goods made from steel, iron, and plastics, and most modern forms of transportation.

Similar Problems: 17.1, 17.3, 17.26

In the United States, the Environmental Protection Agency (EPA) is the governmental agency primarily responsible for overseeing efforts to keep the air clean. Under the 1990 Clean Air Act, the EPA specifies limits on the amount of pollutants allowed in the air anywhere in the United States. The regulation of air quality is a complex undertaking because there are so many kinds of air pollution, and the patterns of pollution change from year to year. The EPA concentrates on emissions that might harm people, including smog, carbon monoxide, lead, particulate matter, sulfur dioxide, and nitrogen dioxide. There are also many other airborne compounds, called air toxins, that can be hazardous to people.

Under the Clean Air Act, federal and state governments can require large sources of pollution, such as power plants or factories, to apply for a permit to release pollutants into the air. The permit specifies the types and quantities of pollutants that can be emitted and the steps the source must take to monitor and control pollution. The EPA can assess fines on sources that exceed allowed emissions. Approximately 35 states have implemented statewide permit programs for air pollution.

Unfortunately, it is not easy for the government to determine optimal emissions standards. Consider again our example with the chemical manufacturers. To calculate the optimal emissions in the entire market, the government would need to know the market demand curve for the chemical, as well as the marginal private and social cost curves. If the only way to reduce pollution is to cut back on the amount of the chemical produced, the efficient emissions standard in Figure 17.2 would be Q^* units of pollutant (the amount of pollutant released into the air when Q^* tons of the chemical are produced).

Even if the regulator could calculate the optimal size of the emissions in the entire market, it must decide how much pollution each firm will be allowed to release. Some firms will be able to reduce (*abate*) emissions at lower costs than other firms. The determination of the socially optimal pollution allowance for each firm will depend on the costs of abatement for each firm in the market. To see why abatement costs matter, suppose the government wants to reduce pollution in the market by one unit. Suppose, also, that it would cost Firm A $1,000 to reduce pollution by one unit, while Firm B could reduce pollution by the same amount at a cost of only $100. It would cost society less to require Firm B to cut back its pollution. An additional cost of emissions standards is that the government must monitor compliance. The EPA or another government agency must measure emissions from factories to ensure that they conform to the permits granted to each.

There are many other examples of the use of government standards and mandates to limit externalities. For example, the Occupational and Safety Hazard Administration

(OSHA) implements requirements for workplace safety that firms must follow for their employees. Most local governments have building codes and zoning regulations that place limits on what kinds of buildings and businesses can be built in various locations. These regulations are designed to reduce negative externalities that can occur when, for example, a factory is built next to a residential neighborhood.

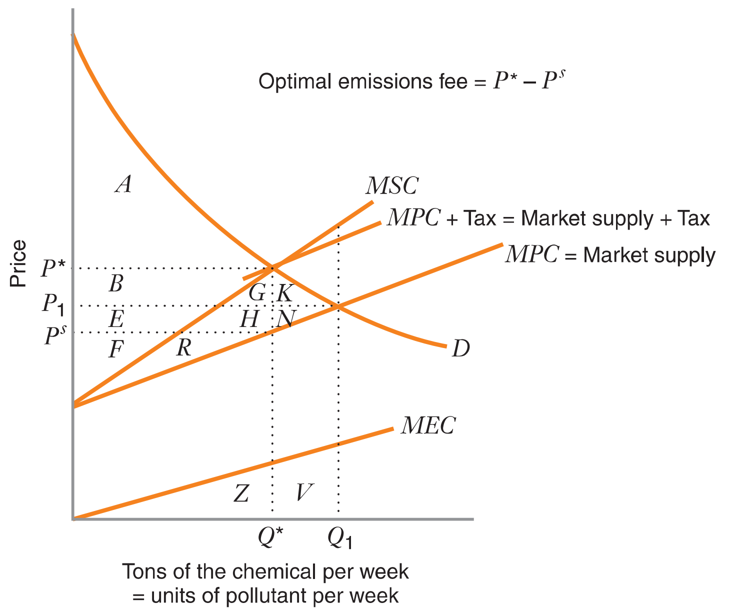
Emissions Fees

emissions fee A tax imposed on pollution that is released into the environment.

The government may also reduce the economic inefficiency from a negative externality by imposing a tax on the firm's output or on the amount of pollutant the firm emits. An **emissions fee** is a tax imposed on pollution that is released into the environment.

Figure 17.3 illustrates the effect of an emissions fee for our example of chemical manufacturing. Suppose the government collects a tax of $\$T$ on each ton of chemical produced. Because each firm emits one unit of pollutant for each ton of chemical produced, we can also view the tax as an emissions fee of $\$T$ on each unit of pollutant.

One way to understand the effect of the tax is to draw a new curve that adds the amount of the tax vertically to the market supply curve, just as we did in Chapter 10 when we studied the effects of an excise tax in a competitive market. The curve labeled



	Equilibrium (with tax)
Consumer surplus	A
Private producer surplus	$F + R$
−Cost of externality	$-R - H - G$
Government receipts from emissions tax	$B + G + E + H$
Net social benefits (consumer surplus + private producer surplus + Government receipts − cost of externality)	$A + B + E + F$

FIGURE 17.3 Optimal Emissions Fee with a Negative Externality
An optimal emissions fee (or tax) will lead to the economically efficient output Q^* in a competitive market. With an optimal fee, the price consumers pay must cover not only the marginal private cost of production, but also the fee. The curve labeled "Market supply + Tax" shows what quantity producers will offer for sale when the price charged to consumers covers the marginal private cost plus the tax. At the optimal tax, the demand curve intersects the "Market supply + Tax" curve at the socially optimal quantity Q^*. Consumers pay P^*, and producers receive a price equal to P^s. The government collects tax revenues equal to areas $B + G + E + H$. There is no deadweight loss with the optimal tax because net benefits are as large as possible ($A + B + E + F$).

"Market supply + Tax" in Figure 17.3 tells us how much producers will offer for sale when the price charged to consumers covers the marginal private cost of production *plus* the tax. The equilibrium with the tax is determined at the intersection of the demand curve and the "Market supply + Tax" curve.

We have chosen the tax to maximize total surplus in Figure 17.3. The market-clearing quantity is Q^*, the same level of output we identified as economically efficient in Figure 17.2. At Q^* the marginal social benefit is P^*, the price consumers pay for each ton of the chemical. Producers receive P^s, which just covers their marginal private cost of production. The government collects a tax of $P^* - P^s$ per ton of the chemical sold (equivalently viewed as an emissions fee of $P^* - P^s$ per unit of pollutant). As the graph shows, the tax just equals the marginal external cost of the pollution emitted when the industry produces the last ton of the chemical. Thus, the marginal social benefit (P^*) equals the marginal private cost (P^s) plus the marginal external cost.

The table in Figure 17.3 gives us another way to see that the tax in the graph is economically efficient. Consumers pay the price P^* for the chemical, resulting in a consumer surplus equal to area A, the area under the demand curve and above P^*. Private producer surplus is areas $F + R$, the area below the price producers receive P^s and above the marginal private cost curve. The external cost is areas $R + H + G$, which is the same as area Z. The government receives tax revenues equal to areas $B + G + E + H$. The net social benefits equal consumer surplus, plus private producer surplus, plus the tax receipts, *minus* the external cost ($-R - H - G$)—that is, areas $A + B + E + F$. This is the same net benefit that we showed to be socially optimal in Figure 17.2.[7]

Fees have an advantage over standards because they provide better incentives and more flexibility for firms in how they reduce emissions. As noted above, a challenge to the use of emissions standards is that the government must decide which factories are granted permits, which requires knowledge of the costs of reducing emissions at each location. Emissions fees do not require the regulator to have such knowledge, nor to decide which factories should reduce pollution. Instead, the tax is imposed on all polluting factories based on the level of their emissions, giving firms incentives to decide the best way in which to reduce their tax liability by reducing emissions. This leads to a more efficient reduction in pollution in two ways.

First, suppose that the industry is made up of two types of firms: those with new factories that use modern manufacturing techniques and emit relatively little pollution for each additional unit of output produced, and those with extremely old factories that use higher-cost manufacturing methods and emit significant amounts of pollution for each additional unit of output produced. The first type of plant has low marginal private costs *and* low marginal external costs, while the second type of plant has high marginal private costs *and* high marginal external costs. If we interpret the *MPC* and *MEC* curves as schedules that depict the marginal private and external costs of individual plants, the first type of plant would be "located" at the "bottom" of the *MPC* and *MEC* curves in Figure 17.2, while the second type of plant would be "located" at the "top" of these curves.

When a fee is imposed, older factories are now less competitive. They will reduce production by a larger amount than new factories, and old factories may even shut down completely if the fee is high enough. By this process, the fee automatically reduces output the most at the factories that are the worst polluters, without the government having to decide which factories pollute more or less.

[7]As we indicated in Chapter 10, one must be careful when using a partial equilibrium analysis like the one in Figure 17.3. A change in the amount of the good consumed in one market may affect market prices, and therefore welfare, elsewhere. Further, there may be additional welfare effects when the government distributes the revenues from the emissions fee somewhere else in the economy. The welfare analysis in Figure 17.3 does not capture these effects.

Second, the emissions fee approach gives firms incentives to make investments in changing their production methods in order to reduce the fees that they have to pay. For example, a firm might install a "scrubber" on the chimneys of its factories to filter out more of the pollutant before emissions are discharged into the atmosphere. As long as the marginal costs of altering production methods to lower emissions are lower than the emissions fees, the firm has an incentive to adopt cleaner production methods.

A recent study illustrates these benefits of fees compared to standards in a different but related context. Out of a desire to reduce emissions of pollutants, the U.S. government in 1978 implemented Corporate Average Fuel Economy (CAFE) standards regulating the sales-weighted average fuel economy of new vehicles such as passenger cars. Over time, regulations have imposed increasingly strict requirements for the fuel efficiency of newly manufactured cars. An alternative fee-based approach would have been to impose a gasoline tax in order to provide incentives to reduce gasoline consumption.

A team of MIT researchers used a general equilibrium macroeconomic model, similar to the kind we discussed in Chapter 16, to estimate the relative efficiency of each approach.[8] Their conclusion was that the CAFE standards actually used by the federal government are highly inefficient, costing six or more times as much as a gasoline tax. For example, the fuel economy standards apply only to newly manufactured cars, and they raise the cost of new cars. Thus increases in standards take many years to have a significant effect on total gasoline consumption, since cars are durable goods. Similarly, consumers can avoid the new and stricter standards by driving their used cars—which tend to pollute more—for longer periods of time. By contrast, a gasoline tax would affect all cars.

While fees provide better incentives and greater flexibility than standards, standards have an advantage over fees in that they provide greater control over the level of the pollution. Unlike a standard, a fee does not provide direct regulation over the total level of emissions. In some cases there may be substantial value to keeping the level of a pollutant within a narrow range. For example, there may be a "tipping point" level of total emissions, beyond which the costs of the hazard rise very rapidly. If that is the case, a standard may be preferred in order to avoid that level of emissions.

Finally, as noted above standards require monitoring, which is itself costly. Fees also require monitoring, if they are imposed on the level of emissions itself. However, if the fee is imposed on production or consumption of the product itself, such as a tax on gasoline monitoring then measuring the level of pollution emissions is not required.

We turn next to the third general method used by governments to reduce negative externalities such as pollution—an emissions market. Before we do, however, Learning-By-Doing Exercise 17.2 will help you understand how an emissions fee may be used to reduce a negative externality, and the welfare implications of doing so.

LEARNING-BY-DOING EXERCISE 17.2

Emissions Fee

Consider a variation of the chemical manufacturing example. Suppose the inverse demand curve for the chemical (which is also the marginal benefit curve) is $P^d = 24 - Q$, where Q is the quantity consumed (in millions of tons per year) when the price consumers pay (in dollars per ton) is P^d.

The inverse supply curve (also the marginal private cost curve) is $MPC = 2 + Q$, where MPC

[8] V. Karplus, S. Paltsev, M. Babiker & J.M. Babiker, "Should a Vehicle Fuel Economy Standard be Combined with an Economy-wide Greenhouse Gas Emissions Constraint? Implications for Energy and Climate Policy in the United States." *Energy Economics*, March 2013.

is the marginal private cost when the industry produces Q.

The industry emits one unit of pollutant for each ton of chemical it produces. As long as there are fewer than 2 million units of pollutant emitted each year, the external cost is zero. But when the pollution exceeds 2 million units, the marginal external cost is positive. The marginal external cost curve is

$$MEC = \begin{cases} 0, & \text{when } Q \leq 2 \\ -2 + Q, & \text{when } Q > 2 \end{cases}$$

where MEC is marginal external cost in dollars per unit of pollutant when Q units of pollutant are released.

Also suppose the government wants to use an emissions fee of \$$T$ per unit of emissions to induce the market to produce the economically efficient amount of the chemical.

Problem

(a) Construct a graph and a table comparing the equilibria with and without the emissions fee:

- Graph the demand, supply (with no emissions fee), marginal external cost, and marginal social cost curves. Label two points on the graph: the point that represents the equilibrium price and quantity when there is no correction for the externality (i.e., no emissions fee) and the point that represents the amount of the chemical the market should supply at the social optimum. Indicate the actual price and quantity at each point.
- Graph the supply curve after the imposition of an emissions fee that induces the production of an economically efficient amount of the chemical. Indicate the price consumers will pay and the price producers will receive.
- In the table, indicate the amount of the emissions fee (dollars per unit) that will lead to the economically efficient production of the chemical. Fill in the table with the following information for the equilibria with and without the fee (indicate both the areas on the graph and the actual dollar amounts): consumer surplus, private producer receipts from the fee, net social benefits, and deadweight loss.

(b) Explain why the following sum is the same with and without the fee: consumer surplus + private producer surplus − external cost + government receipts from the fee + deadweight loss.

Solution

(a) See Figure 17.4. The demand (marginal benefit) curve is D. The supply (marginal private cost) curve is MPC. The marginal external cost curve is MEC (it has a kink in it, at point G, because $MEC = 0$ when $Q \leq 2$). The marginal social cost curve is MSC (the vertical sum of MPC and MEC, with a kink at point V corresponding to the kink in MEC).

The equilibrium with no emissions fee is at point H, where the demand and supply curves intersect. When supply equals demand, $24 - Q = 2 + Q$, or $Q = 11$; since $P^d = 24 - Q$, when $Q = 11$, $P^d = 24 - Q = 13$—that is, at this equilibrium, consumers pay a price of \$13 per ton and producers supply 11 million tons per year.

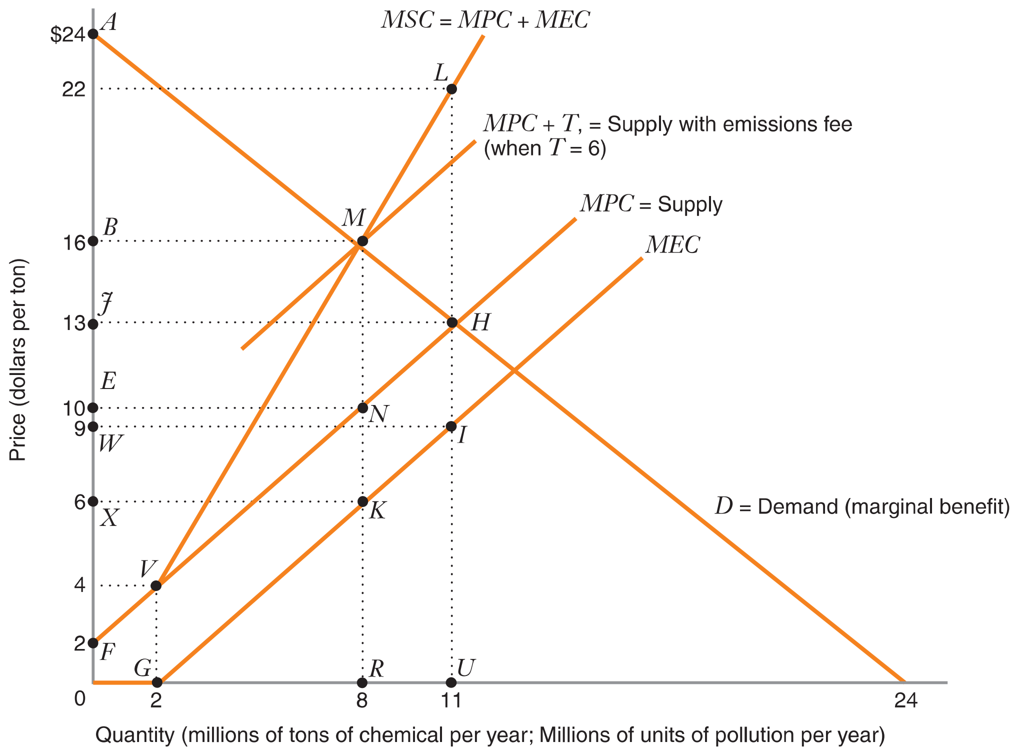
The socially optimal amount of production is at point M, where the demand and marginal social cost curves intersect. When demand equals marginal social cost, $24 - Q = (2 + Q) + (-2 + Q)$ (marginal social cost is the sum of marginal private cost and marginal external cost), or $Q = 8$; when $Q = 8$, $P^d = 24 - Q = 16$—that is, at the social optimum, consumers pay a price of \$16 per ton and producers supply 8 million tons per year.

After the imposition of an emissions fee that induces the production of an economically efficient amount of the chemical, the supply curve will pass through point M (at the socially optimal level of production, $Q = 8$) and will be the sum of the marginal private cost and the fee—that is, the curve $MPC + T$. When $Q = 8$, $MPC = 2 + Q = 10$. Thus, at this equilibrium, consumers pay \$16 per ton and producers receive \$10 per ton, so the emissions fee $T = \$16 - \$10 = \$6$ per unit of emissions.

For each equilibrium the table shows the consumer surplus, private producer surplus, cost of the externality, government receipts from the emissions fee (when a fee is imposed), and the net social benefits.

(b) As the figures in the table show, consumer surplus + private producer surplus − external cost + government receipts + deadweight loss = \$94 million, both with and without the emissions fee. This figure represents the potential net benefit in the market, which is the same whether or not there is a fee. When there is no fee, the market performs inefficiently because of the negative externality, and there is a deadweight loss. (Only \$80.5 million of the \$94 million potential net benefit is captured as net social benefit.) When there is a fee, the market performs efficiently, and the entire potential net benefit is captured. (There is no deadweight loss.)

Similar Problems: 17.4, 17.10, 17.11, 17.12



	No Emissions Fee	Emissions Fee of $6 per Unit
Consumer surplus	*AJH* $60.5 million	*ABM* $32 million
Private producer surplus	*FJH* $60.5 million	*FEN* $32 million
−Cost of externality	−*VLH* (= −*GIU*) −$40.5 million	−*VNM* (= −*GKR*) −$18 million
Government receipts from emissions fee	zero	*ENMB* $48 million
Net social benefits (consumer surplus + private producer surplus − cost of externality + government receipts)	*AMVF* − *MLH* $80.5 million	*AMVF* $94 million

FIGURE 17.4 Emissions Fee
The economically efficient output is 8 million tons, determined by the intersection of the demand and *MSC* curves at point *M*. An emissions fee of $6 per unit of pollutant leads to the efficient level of output. With no emissions fee, the price of the chemical is $13 per ton, and 11 million tons are sold each year. The negative externality leads to an inefficiently high level of pollution and a deadweight loss of $13.5 million per year.

Emissions Trading Markets

A third public policy approach to negative externalities—markets—combines elements of standards and fees. In this approach, the government establishes a fixed number of permits to emit the pollution. It then either auctions them off, or grants them to specific firms on some other basis, such as their historical rate of production. Firms may then buy and sell the right to pollute on a market set up to trade the permits. This approach is like a standard in that the government sets the total allowable level of emissions. However, the ability to trade the permits creates beneficial incentive effects similar to an emissions fee. Firms with higher emissions per unit of output will need more permits to produce the same level of output than will firms with lower emissions per unit of output. This puts firms with cleaner production methods at a competitive advantage. In addition, firms have an incentive to make investments in cleaner production methods, as long as the marginal cost of doing so is lower than the cost of buying more pollution permits. Thus, the market approach allows the government to control the overall level of emissions, which provides incentives so that the total costs of abatement are as low as possible. Ironically, this approach solves a market imperfection by defining a market. In fact, this is an application of the *Coase Theorem* discussed below, as are fishery catch-shares discussed above. In both cases, a property right (in fishing or polluting) is defined by the government in order to reduce a negative externality.

The market approach to reducing negative externalities is often called *cap-and-trade*, because the government caps total emissions by limiting the number of permits issued, and then allows the permits to be traded. This is a relatively new public policy solution, beginning with the Clean Air Act's implementation of a trading market for sulfur dioxide emissions in the United States in 1990. That market proved highly successful (see Application 17.3). Since then, markets have sprung up or been proposed

APPLICATION 17.3

Clearing the Air: The SO_2 Emissions Trading Market as a Response to Acid Rain

In the 1980s there were great concerns in the United States about *acid rain*, a phenomenon caused when airborne pollutants such as sulfur dioxide and nitrogen oxide react with water molecules to form acids, which in turn may harm forests and cause corrosion of stone and steel structures. Since the late 1960s, economists and environmental scientists at the Environmental Protection Agency (EPA) had been considering the new idea of using emissions markets to reduce pollution. Their simulations suggested that such an approach was likely to have substantially lower abatement costs than the conventional public policy methods of standards or fees. Finally, the Clean Air Act of 1990 launched the first cap-and-trade system, implementing a market for the trading of permits to emit sulfur dioxide (SO_2) into the atmosphere.

The SO_2 market was implemented in two phases. In the first phase, emissions permits were allocated to the most SO_2-intensive plants at electric utility companies. These were primarily coal-fired power plants located in the eastern United States. Permits were issued primarily based on each plant's relative production in 1985–1987. Beginning in 1995, these electric plants could only emit sulfur up to the limit of their allocated permits, unless they purchased additional permits from other plants. In 2000, the cap-and-trade system was extended to nearly all fossil-fuel burning electric power facilities in the United States.

The original goal of the program was to reduce emissions of SO_2 to 50 percent below 1980 emissions levels by 2000. At the time the program was implemented, it was estimated that the program's abatement costs would approximately equal the benefits. In fact, the program was highly successful.[9] The emissions reduction goal was achieved well before 2000. It is estimated that emissions have fallen by 40 percent since the program began.[10] Total abatement costs are estimated to be about one fourth of what had been predicted (and much less than the dire warnings of electric utility companies when the emissions market was proposed). By 2000, marginal abatement costs had declined to about 50 percent of 1980 levels. Much of this was due to the closing of older plants that tended to have higher levels of pollution. In fact, the program was so successful compared to expectations that in some years it suffered from over allocation, in which the number of permits exceeded the total required by the industry. Electric power companies banked a large number of credits in such years, which they were allowed to use in later years.

The success of the program has led to implementation of many types of emissions trading markets worldwide, and these markets are now an active part of the global financial industry. For example, Europe has implemented its own SO_2 trading market with even greater reductions in emissions. Unfortunately the current status of the U.S. market is an open question, due to a series of court rulings which have suspended trading since 2010. At the time of this writing, the future of this market is under review by the EPA and U.S. Court of Appeals.

to attempt to reduce emissions of a variety of pollutants. For example, cap-and-trade has been proposed as a possible method to address concerns over CO_2 and climate change.

Common Property

common property A resource, such as a public park, a highway, or the Internet, that anyone can access.

Emissions fees, standards, and trading markets are measures that can help correct economic inefficiency arising when a technology produces an undesired by-product along with some good or service that society values. Negative externalities can also occur in markets that do not involve a by-product, as we have already seen in the use of roadways or the Internet. These are examples of **common property**, that is, resources that anyone can access.

With common property we often observe congestion, a negative externality leading to overuse of a facility. Figure 17.5 illustrates how congestion generates economic inefficiency. The horizontal axis shows the volume of traffic on a highway, measured in vehicles per hour. The vertical axis shows the price of driving (i.e., gas and oil, wear and tear on the car, and the cost of the driver's time spent on this activity). When the traffic volume is below Q_1, there is no congestion. Thus, the marginal external cost is zero for traffic volumes below Q_1. This means that the marginal private cost and the marginal social cost are the same at these low volumes.

When the traffic volume exceeds Q_1, congestion arises. Each new vehicle entering the system adds to the transit time for all vehicles. That is why the marginal external cost rises as traffic volume grows.

[9]See C. Carlson, D. Burtraw, M. Cropper & K. Palmer, "Sulfur Dioxide Control by Electric Utilities: What Are the Gains from Trade?" *Journal of Political Economy*, 2000; and R. Stavins, "What Can We Learn from the Grand Policy Experiment? Lessons from SO_2 Allowance Trading," *Journal of Economic Perspectives*, 1998.

[10]This is possible even if emissions are less than 50 percent of 1980 levels, because the economy grows over time, requiring more total electricity.

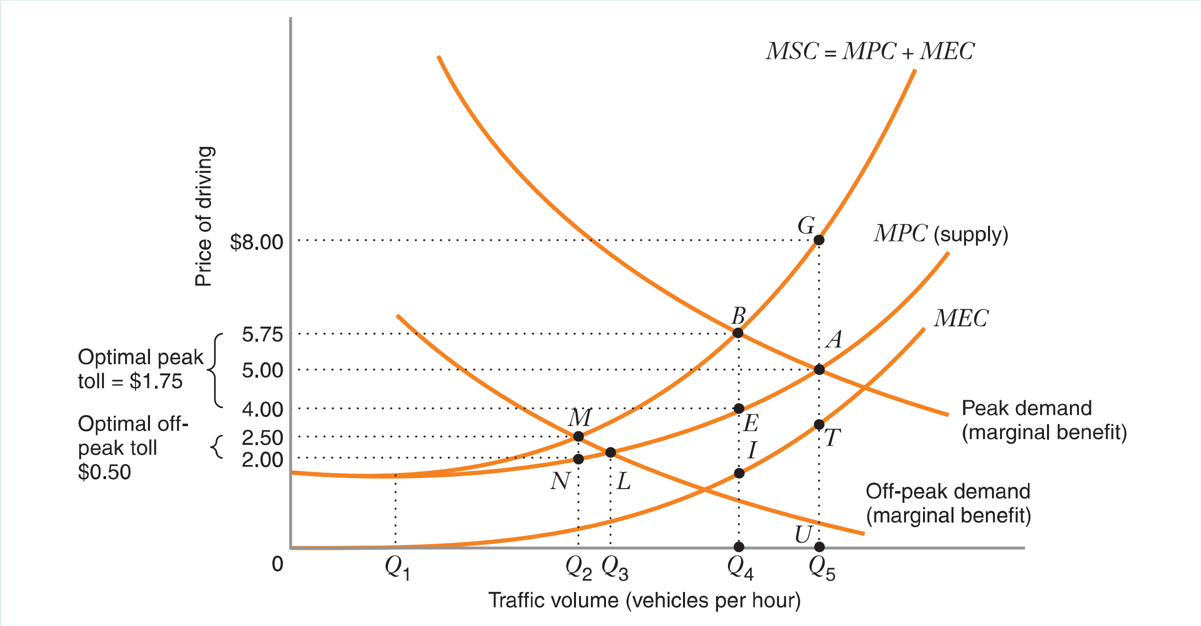


FIGURE 17.5 Congestion Pricing
There is no congestion as long as the level of traffic is lower than Q_1. With higher levels of traffic, the negative congestion externality grows. An optimal toll will lead to a traffic volume where marginal benefit equals marginal social cost. In the peak period, equilibrium with no toll is at point *A*, where deadweight loss is equal to area *ABG.* A toll of $1.75 (the length of line segment *BE*) moves the equilibrium to the economically efficient point *B*. The efficient off-peak toll would be $0.50, the length of the line segment *MN.* In the off-peak period, equilibrium with no toll is at point *L*, where deadweight loss is equal to area *LMN.* In this case, a toll of $0.50 (the length of line segment *MN*) moves the equilibrium to the economically efficient point *M.*

Now let's consider the effects of congestion at two different times of the day. In the peak period (rush hour), the demand for use of the highway is high. Absent any government intervention, the equilibrium traffic level would be Q_5, determined by the intersection of the peak demand curve and the marginal private cost curve, at point *A*. At that point, the marginal benefit for the last vehicle is $5. The marginal private cost is also $5. However, the marginal social cost imposed by the last vehicle is $8 (point *G*). Thus, the marginal external cost is the amount by which the last vehicle increases the costs for *other* vehicles, that is, $3, the length of the segment *AG* (also the length of the segment *TU*).

The socially optimal level of traffic is Q_4, determined by the intersection of the peak demand curve and the marginal social cost curve, at point *B*. At that point, the marginal benefit and the marginal social cost for the last vehicle are both $5.75. The marginal private cost is $4.00 (point *E*). The highway authority could correct for the externality by imposing a toll of $1.75 during the rush hour, bringing the traffic volume to Q_4.

In an off-peak period, the demand for highway use is lower. Without a toll, the equilibrium traffic level would be Q_3, at the intersection of the off-peak demand curve and the marginal private cost curve (point L), where marginal benefit for the last vehicle is \$2.00. The socially optimal traffic level would be Q_2, at the intersection of the off-peak demand curve and the marginal social cost curve (point M), where marginal benefit for the last vehicle is \$2.50. Thus, the efficient off-peak toll would be \$0.50, the length of the line segment MN.

The congestion toll, like an emissions fee, is a tax that can be used to correct for negative externalities. Today, the automated collection devices on most toll roads are not capable of collecting tolls that vary during the day. However, as Application 17.4 shows, with new technology the widespread use of variable tolls is not far away.

Besides congestion, there are other examples of negative externalities with common property. For example, most lakes and rivers, and many hunting grounds, are

APPLICATION 17.4

Congestion Pricing in California

The state of California has had regular fiscal crises in recent years. The recession of 2008–2010 has created the worst in the state's history as tax revenues plummeted. In 2009, California furloughed state workers, froze spending on many projects, and even issued IOUs to contractors and some citizens who were due tax refunds. By early 2010 California had the lowest credit rating of any state. Because of its poor rating, the state would have to pay high interest rates in order to raise funds by issuing general obligation bonds. In fact, in January 2010 the state halted the sale of all state bonds.

An alternative source of funds that the state is considering is revenue-backed bonds. These are bonds that are secured by a dedicated source of funding, such as revenue from toll roads. California was the site of an innovative toll road, Route 91, which in 1995 became the first to be privately financed, and also the first to use *congestion pricing*, with tolls that vary during the day to keep traffic freely moving.

Traffic congestion has long been a problem in Southern California. Route 91 connects the major employment centers of Orange and Los Angeles counties with the rapidly growing residential areas in Riverside and San Bernardino counties. In 1995 a 10-mile, 4-lane toll road was located within the median of the existing 8-lane freeway. In order to use the tollway, motorists must obtain a transponder (electronic device) and prepay money into an account. The transponder functions much like a credit card, containing information on the amount of money that motorists have in their account. Each time a motorist uses the toll road, antennas situated above the highway communicate with the transponder and deduct the toll from that account. There are no toll booths. The rate varies with time of day. The rate on the busiest hour, 4:00 P.M. to 5:00 P.M. eastbound on Thursdays, is \$9.75, the highest toll for any road in the country.

Under a franchise granted by the California Department of Transportation (Caltrans), the \$130 million construction cost for the project was financed by a private entity, the California Private Transportation Company (CPTC). Upon completion of construction, the CPTC transferred ownership of the tollway to Caltrans and leased the facility back from the agency for 35 years. CPTC collected tolls and paid state agencies to provide law enforcement and road maintenance. However, this deal proved controversial (Caltrans had agreed to not widen the freeway alongside the toll road, so as to not increase competition for it), so in 2003 the Orange County Transportation Authority purchased it from the CPTC for \$207.5 million.

Toll roads have proven effective at reducing congestion (and providing a source of revenue for local governments), and their use is expanding gradually throughout the United States. In California, toll roads are now used for several major freeways in Orange County and the Bay Area, and were introduced in areas of downtown Los Angeles in 2012. Many states are adopting transponders for highways tolls, and some states have agreements so that motorists can use a transponder from their home state when driving on toll roads in other states.

APPLICATION 17.5

London's Congestion Charge[11]

On February 17, 2003, the city of London put microeconomic theory into practice when it initiated a £8 charge (about $12) aimed at reducing traffic congestion in the center of the city. Between 7:00 A.M. and 6:30 P.M., Monday through Friday, motorists traveling within a 21-square-kilometer area of London known as the charging zone were required to pay the fee. The charging zone encompassed much of downtown London, including the City, which contains the financial district, and the West End, London's main commercial and entertainment hub.

With a system of streets that had hardly changed since medieval times, central London has long struggled with the problem of traffic congestion. Seventeenth-century author Samuel Pepys wrote about being tangled up in traffic jams with horses and buggies.[12] Modern estimates of the cost of traffic congestion in London were on the order of $300 million per year. Because London offered realistic alternatives to driving (most notably, extensive bus and subway services), a central theme in the debate over traffic congestion had been how to entice people out of their cars and onto public mass transportation.

The first congestion pricing scheme was implemented in Singapore in 1975. Drivers entering the downtown area were charged a fee to reduce traffic. This system was later extended to segments of several freeways. In 1998 the system was fully automated with transponders in cars and automatic charging of fees, so that traffic can flow uninterrupted. Similar systems have been implemented in Edinburgh, Stockholm, and Milan, among other cities.

When the London system was introduced, skepticism about whether the plan would work was widespread, with newspapers talking about "Carmageddon," and the Labour government of Tony Blair disassociating itself from the mayor who had pushed for the system. A number of prominent business groups vocally opposed congestion pricing, arguing that it would severely hurt retailers located in the charging zone. Groups representing motorists and some labor organizations also opposed congestion pricing. Others worried that public transportation would be inadequate to handle the flood of commuters who would turn to it to avoid the fee.

The day-to-day operation of the congestion pricing scheme was outsourced to a private company. Drivers can pay the congestion charge at machines located throughout the zone, as well as at selected retail locations and via the Internet. There are 174 entry and exit points around the charging zone. When a vehicle drives into the zone, its picture is taken by one of 203 video cameras located at entry and exit points and within the charging zone. These cameras (initially developed for antiterrorism efforts) record license plates and match them to lists of individuals who have paid the charge in advance. Owners of vehicles that have not paid the fee are fined from £60 to £180 (about $90 to $270).

Contrary to the fears, the scheme works well. Well over 100,000 vehicles enter the zone and pay the charge each day. Revenues from congestion charges have topped £200,000, well above administrative expenses. There has been a noticeable impact on traffic volume and speed. The number of vehicles entering the zone decreased by about 23 percent, while the average speed increased by about 21 percent. One indication of the success of London's plan was that several parts of the city outside the zone lobbied to be included within it. In 2007 the charging zone was extended westward, roughly doubling in size.

common property. When one person catches fish, a negative externality is imposed on others who would like to fish. The negative externality can become significant when rivalry among commercial fishing enterprises leads to a serious depletion in the stock of fish, jeopardizing fishing harvests in future years. Governments can limit the depletion by imposing taxes or by limiting the quantity of fish that may be caught.

[11]Georgia Santos and Blake Shaffer, "Preliminary Results of the London Congestion Charging Schemes," *Public Works Management & Policy* (2004).

[12]Randy Kennedy, "The Day the Traffic Disappeared," *New York Times*, April 20, 2003.

Negative externalities also arise in the petroleum industry, where there are a number of owners of the mineral rights in large reservoirs of oil or natural gas. When one producer extracts a barrel of oil from a reservoir, it depletes the stock of oil available to other producers. The amount of oil that can be successfully recovered from an oil reservoir depends on the way the oil is extracted. If individual producers vigorously compete to extract oil as quickly as they can, they may damage the reservoir, reducing the total amount that producers can ultimately recover. To enhance total recovery, and to minimize the effects of the negative externality, producers often coordinate production. Frequently, this involves "unitizing" a field, with production operations carried out through a joint venture.

POSITIVE EXTERNALITIES AND ECONOMIC EFFICIENCY

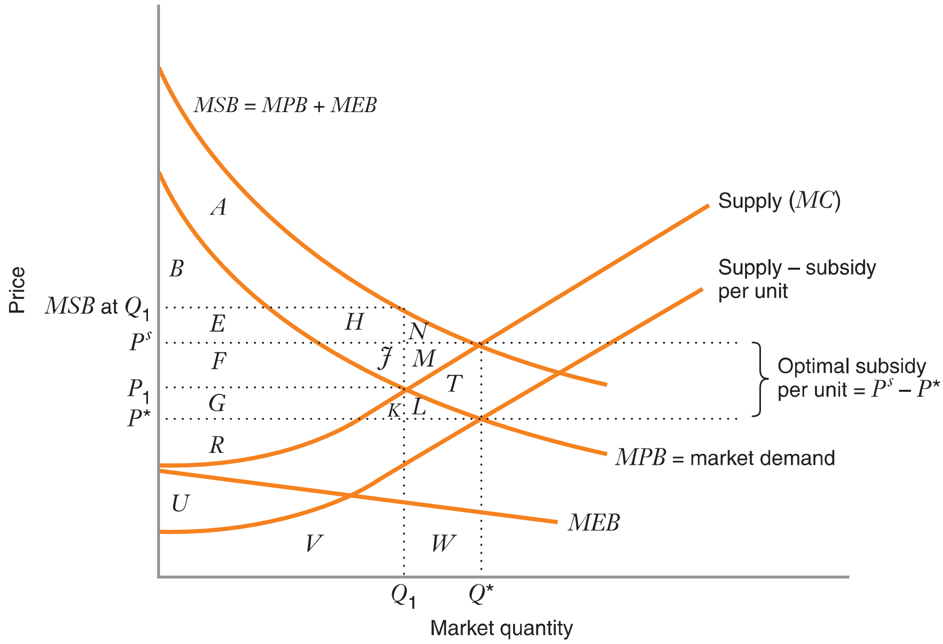
Positive externalities surround us in everyday life. Examples include education, health care, research and development, public transit, and the bandwagon effect we studied in Chapter 5. With a positive externality, the marginal social benefit from the good or service exceeds the marginal private benefit. Other people around a consumer also benefit when the consumer furthers her education or keeps herself in good health. Similarly, when one firm succeeds in developing a new product or technology with a program of research and development, the benefits often spill over to other firms and, ultimately, to consumers.

Just as firms overproduce when there are negative externalities, so do firms underproduce when there are positive externalities. And just as the overproduction is the result of consumers' not taking external costs into account, so is the underproduction a result of consumers' not taking external benefits into account. That is, when you decide whether to buy a good, you consider the benefits you will receive (the marginal private benefit), but you do not consider the benefits your consumption will have for others. Figure 17.6 shows why this underproduction arises in a competitive market with a positive externality.

In Figure 17.6, the market demand curve *MPB* is the horizontal sum of the marginal private benefit curves of all the individuals in the market. The market supply curve *MC* is also the industry marginal cost curve. If there is no correction for the externality, the market will be in equilibrium at the intersection of the demand curve and the supply curve, where the price is P_1 and the market output is Q_1. In equilibrium, private consumer surplus is the area below the *MPB* curve and above P_1 (areas $B + E + F$). Producer surplus is the area below P_1 and above the *MC* curve (areas $G + R$).

Because of the positive externality, there is also an external benefit in the market, as indicated by the marginal external benefit curve *MEB*. The marginal social benefit *MSB* exceeds the marginal private benefit by the amount of the marginal external benefit—that is, $MSB = MPB + MEB$. Again at the equilibrium without any correction for the externality (where market output is Q_1), the size of the external benefit is the area below the *MSB* curve and above the *MPB* curve (areas $A + H + J$), which is equal to the area under the *MEB* curve (areas $U + V$). Thus, at this equilibrium, the net social benefit is the sum of the private consumer surplus, the producer surplus, and the benefit from the externality (areas $A + B + E + F + G + H + J + R$).

Why does the competitive market fail to produce an economically efficient amount of output? In equilibrium the marginal cost of the last unit produced is P_1,



	Equilibrium (no subsidy)	**Social Optimum (equilibrium with subsidy)**	**Difference in Benefits between Social Optimum and Equilibrium with No Subsidy**
Private consumer surplus	*B* + *E* + *F*	*B* + *E* + *F* + *G* + *K* + *L*	*G* + *K* + *L*
Producer surplus	*G* + *R*	*F* + *G* + *R* + *J* + *M*	*F* + *J* + *M*
Benefit from externality	*A* + *H* + *J*	*A* + *H* + *J* + *M* + *N* + *T*	*M* + *N* + *T*
−Government cost from subsidy	zero	−*F* − *G* − *J* − *K* − *L* − *M* − *T*	−*F* − *G* − *J* − *K* − *L* − *M* − *T*
Net social benefits (private consumer surplus + producer surplus + benefit from externality − government cost)	*A* + *B* + *E* + *F* + *G* + *H* + *J* + *R*	*A* + *B* + *E* + *F* + *G* + *H* + *J* + *M* + *N* + *R*	*M* + *N*

FIGURE 17.6 Optimal Subsidy with a Positive Externality
With a positive externality, the marginal social benefit *MSB* equals the marginal private benefit *MPB* plus the marginal external benefit *MEB*. In a competitive market with no correction for the externality, the equilibrium is determined by the intersection of the demand curve (i.e., the marginal private benefit curve *MPB*) and the supply curve. The equilibrium price is P_1 and the quantity is Q_1.

The socially optimal output is Q^*, determined by the intersection of the supply curve and the marginal social benefit curve. The externality leads the market to underproduce by the amount ($Q^* - Q_1$). The social optimum can be reached with a government subsidy. The optimal subsidy per unit is the difference between the price received by producers P^s and the price paid by consumers P^* at the efficient quantity Q^*. The optimal subsidy eliminates the deadweight loss (area *M* + *N*) that would arise without the subsidy.

APPLICATION 17.6

Knowledge Spillovers and Innovation

Economists have long recognized that an important positive externality is *knowledge spillovers*. Exchange of new ideas, and learning from the creativity of others, often inspire innovations by others. For example, one pharmaceutical firm may develop a new blockbuster drug using a specific type of organic molecule. Other firms may be inspired by this development to focus research and development on similar molecules, which may lead to additional new drugs. Because of such knowledge spillovers, governments often subsidize investments in research and development, especially through universities.

Like most externalities, knowledge spillovers arise because of imperfect property rights. If a firm could obtain legal protection for all of the economic applications of a new idea (via patent, copyright, or trademark protection), it would certainly do so. The firm would then be able to profit from all of these applications, possibly by selling or renting the rights to some of those applications to others. In principal this would lead to greater innovation. However, as we have discussed earlier in the text, there is a tradeoff, since such protections would also create monopoly profits for the firm. In addition, it is not obvious that a single firm would be able to profitably exploit all of the possible applications of its new ideas. Creativity often arises from combining ideas and information from different people or firms, applying one idea in an unexpected new setting. For these reasons, economists generally argue that knowledge spillovers have strong positive effects on innovation and economic growth.

Economists who study innovation describe two relevant sources of knowledge spillovers. The first is *MAR Spillovers*, named after the economists who first analyzed them, Alfred Marshall (in 1890), Kenneth Arrow, and Paul Romer. MAR spillovers occur when there is a concentration of firms in the same industry located in the same geographic area. Silicon Valley is a prime example of MAR spillovers, with thousands of high-technology companies located in a small area. When there is a concentration of firms using related technologies, employees from different firms are more likely to interact with each other professionally or socially, or switch employers. These interactions increase the likelihood that new ideas will proliferate across firms, generating additional innovations.

The second form of knowledge spillovers is *Jacobs Spillovers*, named after Jane Jacobs. She argued that knowledge spillovers may be created by having a concentration of firms from *diverse* industries (in contrast to MAR spillovers), because innovations in one industry may be applicable in other industries too. Indeed, Jacobs spillovers are based on the idea that much creativity comes from interdisciplinary interactions. This same idea is why universities are now building interdisciplinary research labs, hoping for new innovations across departments (e.g., application of information technology to medicine).

A recent study by Gerard Carlino summarizes prior empirical research on these questions and provides some new evidence.[13] Evidence suggests that spillovers from concentration of firms in the same area are indeed important to innovation. For example, in the 1990s 92 percent of all patents went to residents of metropolitan areas, even though metropolitan areas comprise only 75 percent of the U.S. population. For example, San Jose, California had 17.6 patents per 10,000 citizens, compared to 2.5 nationally. Table 17.1 shows the top and bottom 10 U.S. cities, ranked by number of patents per 10,000 citizens in the 1990s. Economists have also studied which existing patents are cited by a new patent application. Cited patents are 5–10 times more likely to originate in the same metropolitan area as the new patent, providing strong evidence that personal interactions between employees across firms create knowledge spillovers.

[13]Gerald Carlino, "Knowledge Spillovers: Cities' Role in the New Economy," *Business Review*, Federal Reserve Bank of Philadelphia, Quarter 4, 2001.

TABLE 17.1 Patents per 10,000 Citizens, U.S. Metropolitan Areas

Top 10		*Bottom 10*	
Metropolitan Area	**Patents per 10,000 Citizens**	**Metropolitan Area**	**Patents per 10,000 Citizens**
San Jose, CA	17.6	Rockford, IL	4.0
Boise City, ID	14.1	Cincinnati, OH	3.9
Rochester, NY	13.0	Hartford, CT	3.8
Boulder, CO	11.2	Monmouth-Ocean, NJ	3.8
Trenton, NJ	10.5	Akron, OH	3.8
Burlington, VT	9.0	Allentown, PA	3.8
Rochester, MN	9.0	Greeley, CO	3.8
Poughkeepsie, NY	8.8	Seattle, WA	3.8
Ann Arbor, MI	8.3	Kalamazoo, MI	3.8
Austin, TX	8.0	Sheyboygan, WI	3.8

Source: Carlino (2001).

which is *lower* than the marginal social benefit for that unit. Thus, the net social benefit from producing *another* unit is positive. The economically efficient market output is Q^*, where the marginal social benefit *equals* the marginal cost for the last unit produced. Net benefits would increase if the market expanded production to Q^*. The failure to produce these additional units introduces a deadweight loss equal to areas $M + N$.

How might public policy correct for the economic inefficiency resulting from underproduction with a positive externality? One possible way would be to subsidize production of the good. (Recall from Chapter 10 that a subsidy is like a negative tax. We learned there how a subsidy on each unit supplied stimulates production.)

How large must the subsidy be to lead the market to produce the efficient output Q^*? As shown in Figure 17.6, to supply the last unit, producers will need to receive the price P^s. However, consumers are willing to pay only P^* for that unit. Thus, there is a gap of $P^s - P^*$ between the price producers require and the one consumers will pay. Therefore, if the government provides a subsidy equal to $P^s - P^*$, it will induce producers to provide that unit and consumers to purchase it.

The table in Figure 17.6 compares the equilibrium with no subsidy to the equilibrium at the social optimum (the equilibrium induced by the government subsidy). With the subsidy, private consumer surplus increases by areas $G + K + L$, producer surplus increases by areas $F + J + M$, the external benefit increases by areas $M + N + T$, and the cost to the government is equal to areas $F + G + J + K + L + M + T$. Thus, with the subsidy, the net social benefit increases by areas $M + N$, and there is no deadweight loss.[14]

[14]Once again, we observe that one must use caution when using a partial equilibrium analysis like the one in Figure 17.6. If the government subsidizes one market, it must collect the funds for the subsidy (perhaps introducing a deadweight loss) somewhere else in the economy. The welfare analysis in Figure 17.6 does not capture these effects.

PROPERTY RIGHTS AND THE COASE THEOREM

property right The exclusive control over the use of an asset or resource.

So far we have examined how the government might correct for externalities using taxes (emissions fees and tolls) and regulating quantity (emissions standards). As an alternative, the government can assign a **property right**, that is, the exclusive control over the use of an asset or resource, without interference by others.

Why are property rights important in dealing with externalities? Let's return to our example of a chemical manufacturing process that emits pollution as a by-product. When we described the negative externality, we observed that manufacturers did not have to compensate anyone when they released pollutants into the air. That is why the firms based their production decisions on private marginal costs that did not include the harm that pollution brought to the environment. The costs of pollution were external to the manufacturers.

In that example we also assumed that no one in the surrounding community had a legal right to clean air. If the community owned a property right to clean air, it could have required firms to compensate it for the right to pollute. If a firm were to continue producing the chemical, its marginal private cost would then include the cost of pollution. In other words, the costs of pollution would be internal to the firm instead of external.

In 1960 Ronald Coase developed a fundamental theorem demonstrating how the problem of externalities could be addressed by assigning property rights.[15] He illustrated the idea with an example involving two farms. Farm *A* raises cattle, and the cattle occasionally stray onto the land of a neighboring farm, Farm *B*, which raises crops. Farm *A*'s cattle impose a negative externality by damaging the crops on Farm *B*.

Coase addressed the following issues: Should the cattle be allowed to roam on the property of Farm *B*? Can the owner of Farm *B* require the owner of Farm *A* to construct a fence to restrain the cattle? If so, who should pay for the fence? Does it matter whether the property rights are assigned to the owners of Farm *A* or Farm *B*?

Coase Theorem The theorem which states that regardless of how property rights are assigned with an externality, the allocation of resources will be efficient when the parties can costlessly bargain with each other.

The **Coase Theorem** states that, regardless of how property rights are assigned with an externality, the allocation of resources will be efficient when the parties can costlessly bargain with each other. If the owner of *A* has the right to let his cattle roam on *B*'s land, *B*'s owner will pay *A*'s owner to build a fence when the damage to *B*'s crops exceeds the cost of the fence. If the cost of the fence exceeds the damage to the crops, it will not be in the interest of owner *B* to pay for the fence, and the cattle will roam. In other words, when it is socially efficient to construct the fence, the fence will be built to eliminate the externality.

Suppose, instead, that the property rights are assigned to owner *B*, so that *A* has to compensate *B* for any damage. Owner *A* would build a fence if the damage to *B*'s crops exceeds the cost of the fence. However, if the cost of the fence is greater than the damage to the crops, then owner *A* will compensate owner *B* for the damage, and, once again, the cattle will roam.

The example nicely demonstrates the remarkable point of the Coase Theorem. Regardless of whether the property rights are assigned to the owner of Farm *A* or to

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

the owner of Farm *B*, the outcome is the same *and* it is socially efficient. The fence will be built when the fence costs less than the damage to the crops, and it will not be built when the fence costs more than the damage.

While the Coase Theorem claims that the allocation of resources will be economically efficient, regardless of the assignment of property rights, the *distribution* of resources very much depends on who holds the property rights. In Learning-By-Doing Exercise 17.3, suppose the cost of the fence is $2,000 and the cost of the damage is $1,000. No one pays for a fence. Thus, the owner of the property rights is $1,000 better off than he or she would be without the property rights.

If the cost of the damage is $4,000, someone will pay for a fence. If *A* owns the property rights, *B* pays for the fence. However, if *B* owns the rights, *A* pays for it. Thus, the owner of the property rights is $2,000 better off than he or she would be without the property rights.

In this example, the "bargaining" between the parties is extremely simple once the property rights are defined. If any money is transferred between the parties, the amount of the transfer is the lesser of two amounts: the cost of the fence or the cost of the damage to the crops.

Coase did not explore richer opportunities for bargaining in his work. However, his ideas can be applied to more complex settings where bargaining is possible. Suppose the cost of crop damage is $4,000 if the cattle stray to Farm *B*, but now let's add another fencing option. The cost of fencing owner *A*'s property is $2,000; alternatively, at a cost of $3,000 owner *B* could build a fence around his property to keep the cattle out.

LEARNING-BY-DOING EXERCISE 17.3

The Coase Theorem

Problem

(a) In the case of the roaming cattle just described, suppose it is costless for the parties to bargain. Verify the Coase Theorem when the cost of the fence is $2,000 and the cost of the damage is $1,000.

(b) Verify the Coase Theorem if the fence costs $2,000 and the damage cost is $4,000.

Solution

(a) Suppose the property rights are assigned to *A*. Owner *B* can either pay for a fence costing $2,000, or live with the damage of $1,000. *B* therefore does not find it worthwhile to pay for a fence, and the cattle will roam. Owner *B* receives no compensation for the damage of $1,000.

Suppose the property rights are assigned to *B*. Owner *A* can either spend $2,000 to build a fence to prevent damage or build no fence and pay $1,000 to owner *B* to compensate for damage. Owner *A* does not find it worthwhile to pay for a fence, and the cattle will roam. The damage to *B* is $1,000, but *A* will compensate *B*.

With either property rights assignment, the outcome is the same: the cattle will roam. It is economically efficient to build no fence because the fence costs more than the damage from roaming cattle.

(b) Suppose the property rights are assigned to *A*. Owner *B* now finds it worthwhile to pay for a fence, and the cattle will not roam.

Suppose the property rights are assigned to *B*. Owner *A* now finds it worthwhile to pay for a fence, and the cattle will not roam.

Once again, with either assignment of the property right, the outcome is the same: the cattle will not roam. It is economically efficient to pay for the fence because the fence costs less than the damage that would have occurred from roaming cattle.

Similar Problems: 17.14, 17.15, 17.16, 17.19, 17.20

What happens when we assign the property rights to owner *B*? Owner *A* has three options: (1) fence in Farm *A* at a cost of $2000, (2) offer owner *B* $3,000 to fence in Farm *B*, or (3) let the cattle roam and pay owner *B* $4,000 to cover crop damage. To minimize his cost, owner *A* will fence in Farm *A*.

Suppose the property rights belong to owner *A*. Owner *B* has three options: (1) fence in Farm *B* at a cost of $3,000, (2) offer owner *A* a payment (to be discussed below) to fence in Farm *A*, or (3) do nothing and incur $4,000 worth of crop damage. Under the second option, there is now room for bargaining. Owner *B* would be willing to offer owner *A* up to $3,000 if *A* will fence in his property. (Owner *B* would offer no more than $3,000 to *A* because *B* can fence in Farm *B* at that cost.) At the same time, owner *A* will accept no less than $2,000 to fence in his property. There is an opportunity for both parties to be better off if they agree that *B* will pay *A* some amount between $2,000 and $3,000 to fence in Farm *A*. For example, the two parties may agree to split the difference, with owner *A* receiving a payment of $2,500 to build a fence around his farm.

As before, the outcome is the same, regardless of who owns the property right: Farm *A* will be fenced. Further, the outcome is socially efficient because the cost to fence in Farm *A* is less than the cost to fence in Farm *B* *and* less than the damage caused to the crop farmer if the cattle roam.

To summarize, the Coase Theorem shows that, as long as bargaining is costless, assigning property rights for an externality leads to an efficient outcome, regardless of who owns the rights. However, this powerful proposition depends crucially on the assumption that bargaining is costless. If the bargaining process itself is costly, then the parties might not find it worthwhile to negotiate. Consider our earlier example of the manufacturers who pollute the air as they produce a chemical. If pollution harms thousands of people, it may not be easy for the victims of the negative externality to organize themselves to bargain about compensation. Similarly, if there are many firms in the industry, it may also be costly for them to organize.

There are other potential difficulties with bargaining. If the parties do not know the costs and benefits of reducing the externality, or if they have different perceptions about these costs and benefits, then bargaining may not lead to an efficient outcome. Finally, both parties must be willing to enter into agreements that are mutually beneficial. If one of the parties simply refuses to bargain or refuses to give the other party an acceptable compensation, it may not be possible to achieve an efficient resource allocation.

17.3 PUBLIC GOODS

We have now learned why a competitive market fails to produce the socially optimal output when there are externalities. For goods with positive externalities, consumers make purchasing decisions based on the marginal private benefits, which are lower than marginal social benefits. Thus, the market produces a lower quantity than the social optimum. Private benefits may be so low that a good is simply not provided at all, even though production of the good would lead to positive net social benefits.

In this section we examine another kind of good that will be undersupplied by the market, public goods. Public goods benefit all consumers even though individual consumers do not pay for the provision of the good. Public goods have two characteristics: They are nonrival goods and nonexclusive goods.

With a **nonrival good**, consumption by one person does not reduce the quantity that can be consumed by others. An example of a nonrival good is public broadcasting. When one viewer tunes in, the number of others who can watch or listen is not diminished. National defense is also a nonrival good. When one person in a community receives protection, the amount of protection available to other consumers is not reduced. The marginal cost of providing output to another consumer of a nonrival good is zero.

nonrival good When consumption of a good by one person does not reduce the quantity that can be consumed by others.

By contrast, most goods we encounter in everyday life are **rival goods**. With a given level of production of a rival good, the consumption of the good by one person reduces the amount available to others. For example, when you buy a pair of jeans, a soccer ball, or a computer, you have foreclosed the possibility that anyone else can buy that particular item.

rival goods When consumption of a good by one person reduces the quantity that can be consumed by others.

A **nonexclusive good** is a good that, once produced, is accessible to all consumers; no one can be excluded from consuming the good after it is produced. Once a nonexclusive good is produced, a consumer can benefit from the good even if he does not pay for it. Examples of nonexclusive goods are abundant, including national defense, public parks, television and radio signals, and artwork in public places. By contrast, an **exclusive good** is one to which consumers may be denied access.

nonexclusive good A good that, once produced, is accessible to all consumers; no one can be excluded from consuming such a good after it is produced.

exclusive good A good to which consumers may be denied access.

Many goods are both exclusive and rival. Examples include computers, paintings, items of clothing, and automobiles. Suppose a manufacturer makes 1,000 automobiles. When a consumer buys one of them, only 999 are left for others to purchase (i.e., the good is rival). In addition, the manufacturer can deny consumers access to the automobile—to enjoy the benefits of an automobile, the consumer must pay for it (i.e., the good is exclusive).

Some goods are nonexclusive but rival. Anyone may reserve a picnic table at a public park, but when one person reserves the table on a given day, it is not available to others at that time. Hunting in public game areas is nonexclusive because everyone has access to the game; however, hunters reduce the stock of game left for others when they bag their quarry.

Finally, a good can be nonrival but exclusive. A pay-TV channel is exclusive because producers can scramble the channel to control access. But the channel is also nonrival. When someone purchases the right to view the channel, this action does not reduce the opportunity for other viewers to do the same.

As we have observed, public goods, such as national defense and public broadcasting, are both nonrival and nonexclusive. To avoid confusion as we study public goods, it is important to keep in mind that many goods that are publicly provided are not public goods, being either rival or exclusive or even both. For example, because a public university has a limited capacity, education there can be a rival good. When one student enrolls, another prospective student might be displaced. Further, education at a public university can be an exclusive good because the university can deny admission to an applicant and because the university can exclude any student who does not pay the required tuition.

EFFICIENT PROVISION OF A PUBLIC GOOD

How much of a public good should be provided to maximize net social benefits? As with other goods, a public good should be provided as long as the marginal benefit of an additional unit is at least as great as the marginal cost of that unit.

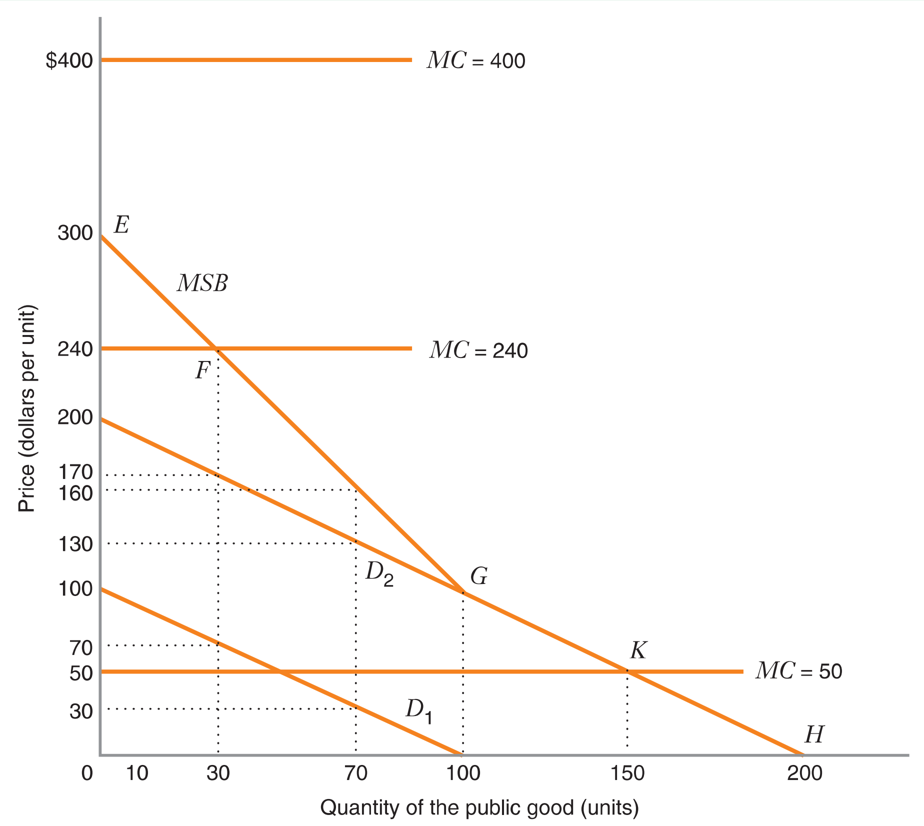
The marginal cost of a public good is the opportunity cost of using economic resources to produce that good rather than other goods. Because public goods are nonrival, many consumers may enjoy the benefits of an additional unit. The marginal benefit is thus the sum of the benefits of all the people who value the additional unit.

Figure 17.7 illustrates the efficient level of production for a public good. For simplicity, let's assume that there are only two consumers in the market. D_1 is the demand curve for the public good by the first consumer, and D_2 is the demand curve for the second consumer. The height of a consumer's demand curve at any quantity shows the marginal benefit of an additional unit of the good to that consumer. For example, the first consumer has a marginal benefit of \$30 per year for the 70th unit. The second consumer has a marginal benefit of \$130 for the same unit.

Because the public good is nonexclusive, both consumers have access to the good. Thus, the marginal social benefit of the 70th unit is just the vertical sum of the marginal benefits for the two consumers: $\$130 + \$30 = \$160$. In Figure 17.7, the marginal social benefit curve is the kinked curve *EGH*. Between *G* and *H* (that is, when $Q > 100$) the marginal social benefit curve coincides with D_2 because the first consumer is not willing to pay anything for these units. (Beyond point

FIGURE 17.7
Efficient Provision of a Public Good
The marginal social benefit of a public good is the vertical sum of the demand curves for the consumers in the market. The marginal social benefit curve is *EGH*. When the marginal cost of the public good is \$240, the economically efficient level of production is 30 units, the output at which the marginal cost and marginal social benefit curves intersect.

If the marginal cost is \$50, the efficient level of production is 150 units; if the marginal cost is \$400, it is inefficient to provide the good at all.



H—that is, when $Q > 200$—the marginal social benefit curve coincides with the horizontal access because neither consumer is willing to pay anything for those units.)

We can now determine the economically efficient level of production for the public good. Suppose that the marginal cost of the public good is \$240. The economically efficient quantity is the quantity at which marginal social benefit equals marginal cost, or 30 units. It would not be efficient to produce more than 30 units because the marginal cost would exceed the marginal social benefit for each additional unit produced. For example, as we have already shown, the marginal social benefit of the 70th unit is \$160. However, this is less than the marginal cost, \$240. Therefore, it would not be socially efficient to provide the 70th unit of the public good.

Similarly, it would not be efficient to produce less than 30 units of the good. Over this range of production, the marginal social benefit exceeds the marginal cost. Thus, it would be economically efficient to expand production until the marginal social benefit just equals the marginal cost.

At the efficient level of output of 30 units, the marginal benefit for the first consumer is \$70, and the marginal benefit for the second consumer is \$170. Thus, the marginal social benefit of the 30th unit is \$240, which just equals the marginal cost of that unit.

This example shows that it may be socially optimal to provide the good even if no consumer alone is willing to pay enough to cover the marginal cost. Because the good is nonrival, marginal social benefit is the sum of the willingness to pay by all consumers, not simply the willingness to pay by any individual alone.

Learning-By-Doing Exercise 17.4 will help you better understand how to find the optimal amount of a public good, both graphically and algebraically. It will also help you understand how to sum demand curves vertically.

LEARNING-BY-DOING EXERCISE 17.4

Optimal Provision of a Public Good

In Figure 17.7, demand curve D_1 is $P_1 = 100 - Q$, and demand curve D_2 is $P_2 = 200 - Q$. (We have written these in *inverse* form, with price on the left and quantity on the right, for reasons explained below.)

Problem

(a) Suppose the marginal cost of the public good is \$240. Determine the efficient level of production of the public good algebraically.

(b) Suppose the marginal cost of the public good is \$50. Determine the efficient level of production of the public good both graphically and algebraically.

(c) Suppose the marginal cost of the public good is \$400. Determine the efficient level of production of the public good both graphically and algebraically.

Solution

(a) The marginal social benefit curve *MSB* with a public good is the *vertical* sum of the individual consumer demand curves. When we sum vertically, we add *prices* (i.e., willingness to pay); thus, $MSB = P_1 + P_2 = (100 - Q) + (200 - Q) = 300 - 2Q$. At the efficient level of production, $MSB = MC$, or $300 - 2Q = 240$, or $Q = 30$ units. (As noted above, we need to use the inverse form of the demand curves in order to add prices.)

(b) If the marginal cost is \$50, we find the efficient level of production graphically by finding the intersection of the *MSB* and *MC* curves. As shown in Figure 17.7, this occurs at point *K*, where $Q = 150$ units. To find this optimum algebraically, we must recall that $P_1 = 0$ when $Q > 100$. In this case, then, $MSB = P_1 + P_2 = 0 + P_2 =$

$P_2 = 200 - Q$. When $MSB = MC$, $200 - Q = 50$, or $Q = 150$.

(c) If the marginal cost is $400, the marginal cost curve lies above the entire marginal social benefit curve, as shown in Figure 17.7. Therefore, it is not efficient to produce any of the public good. Algebraically, if $MSB = MC$, then $300 - 2Q = 400$, or $Q = -50$. This tells us that the *MSB* and *MC* curves do not intersect when $Q > 0$ (i.e., there is no positive efficient level of production of the public good).

Here is a hint that you may find useful in adding demand curves. First, you need to know whether you should add the demand curves vertically or horizontally. As we have shown in this chapter, if you need to find the optimal level of a public good, you need to add demands *vertically*. To add the demand curves vertically, write the individual demand curves as *inverse* demands and then add them up, as we have just done.

By contrast, in Chapter 5 we showed that, to construct an ordinary market demand curve from individual demand curves, you must add the demand curves *horizontally* because you want to know the total quantity demanded at any price. The goods we considered in Chapter 5 were *rival* goods. That is why we did not add consumers' willingness to pay to determine the value of an extra unit of the good. To add the demand curves horizontally, write the individual demand curves in their *normal* form, with Q on the left-hand side and P on the right-hand side. To review how to add demand curves horizontally, you might refer to the discussion following Table 5.1.

Similar Problems: 17.21, 17.22, 17.23, 17.24, 17.25

THE FREE-RIDER PROBLEM

free rider A consumer or producer who does not pay for a nonexclusive good, anticipating that others will pay.

There are often thousands, or even millions, of consumers of public goods such as a dam, a public park, or public broadcasting. To finance an efficient level of output for a public good, consumers must jointly agree that everyone contributes an amount equal to his own willingness to pay. However, since the provision of a public good is nonexclusive, everyone benefits once the public good is provided. Consequently, individuals have no incentive to pay as much as the good is really worth to them. A consumer can behave as a **free rider**, paying nothing for a good while anticipating that others will contribute.

APPLICATION 17.7

Free Riding on the Public Airwaves[16]

Public television and public radio are examples of public goods. They are nonrival and nonexclusive. With millions of viewers, it is not surprising that there are many free riders in public broadcasting.

PBS (Public Broadcasting System), a private, nonprofit media enterprise, provides much of the programming for the (approximately) 350 public television stations in the United States. Each month public television serves nearly 122 million viewers. But most viewers are free riders. Fewer than 5 million individuals and families contribute to public television each year, with donations, pledges, and membership fees that compromise approximately 24 percent of PBS's total revenues. PBS receives another 14 percent from businesses, about 8 percent from foundations, and 10 percent from miscellaneous sources. Roughly 43 percent of all of its funding comes from federal, state, and local governments.

The story is much the same for public radio. NPR (National Public Radio) is a private, nonprofit company with approximately 900 member radio stations and about 64 million listeners per month. However, only 34 percent of its funding comes from subscribers. About 20 percent comes from businesses and 10 percent from foundations; 21 percent of NPR's funding comes from the government at various levels. Because of the free-rider problem, funds to support public broadcasting must come from a variety of other sources. For decades governmental subsidies have remained important for the financial viability of the industry.

[16] "Public Broadcasting Revenue, Fiscal Year 2010," *Corporation for Public Broadcasting* (2011).

The free-rider problem makes it difficult for a private market to provide public goods efficiently. It is generally easier to organize effective efforts to collect voluntary funding when the number of people involved in paying for a project is small because each person recognizes that his or her contribution is important. However, when the number of consumers of a public good becomes large, it is more likely that many consumers will act as free riders. Public intervention may be necessary to ensure the provision of a socially beneficial public good. The government therefore often produces a public good itself or subsidizes the enterprises that produce the good.

CHAPTER SUMMARY

- An externality arises when the actions of any decision maker, either a consumer or a producer, affect the benefits of other consumers or production costs of other firms in the market in ways other than through changes in prices. An externality that reduces the well-being of others is a negative externality. An externality that brings benefit to others is a positive externality.
- Externalities cause *market failure* in competitive markets. With an externality, the *invisible hand* does not lead an otherwise competitive market to produce an economically efficient level of the good.
- With a negative production externality (like pollution), the private marginal cost to a producer is less than the social marginal cost. With a negative consumption externality (like secondhand smoke from cigarettes), a consumer does not pay for the cost of his own actions imposed on other people. Consequently, a competitive market produces more of the good than is socially optimal. The government may attempt to improve economic efficiency by reducing the amount of the good by imposing a quota (such as an emissions standard) or a tax (such as an emissions fee). **(LBD Exercises 17.1, 17.2)**
- Negative externalities can also arise in markets that involve a common property (a resource anyone can access). With common property, the negative externality of congestion often occurs. In such cases, government can impose a tax on use of the common property in order to achieve economic efficiency.
- With a positive externality (like education or immunization to prevent the spread of contagious diseases), the private marginal benefit is less than the social marginal benefit. Consequently, a competitive market produces less of the positive externality than is socially optimal. The government may attempt to improve efficiency by stimulating output with a production subsidy.
- Inefficiencies arising from externalities may be eliminated if property rights to externalities are clearly assigned and parties can bargain. The Coase Theorem shows that when parties can costlessly bargain, the outcome of the bargain will be economically efficient, regardless of which party holds the property rights. However, it may be difficult to achieve an efficient outcome with bargaining if there are many parties involved, or if bargaining is a costly process. Although the assignment of the property rights does not affect economic efficiency, it will affect the distribution of income. **(LBD Exercise 17.3)**
- A public good is a good that is nonrival and nonexclusive. The marginal social benefit curve for a public good is the vertical sum of the individual demand curves for that good. A public good is provided efficiently when its marginal social benefit equals its marginal cost.
- A public good is likely to be underproduced because consumers often act as free riders, benefiting from the good but not paying for it. To ensure the provision of a socially beneficial public good, the government often produces the good itself or subsidizes enterprises that produce the good. **(LBD Exercise 17.4)**

REVIEW QUESTIONS

1. What is the difference between a positive externality and a negative externality? Describe an example of each.

2. Why does an otherwise competitive market with a negative externality produce more output than would be economically efficient?

3. Why does an otherwise competitive market with a positive externality produce less output than would be economically efficient?

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