

>> Externalities

WHO'LL STOP THE RAIN?

MILLIONS OF PEOPLE IN THE NORTH-eastern United States can think of no better way to relax than fishing in one of the region's thousands of lakes. But in the 1960s avid fishermen noticed something alarming: lakes that had formerly teemed with fish were now almost empty. What happened?

The answer turned out to be acid rain, caused mainly by coal-burning power plants. When coal is burned, it releases sulfur dioxide and nitric oxide into the atmosphere; these gases react with water, producing sulfuric acid (H_2SO_4) and nitric acid (HNO_3). The result in the Northeast, downwind from the nation's industrial heartland, was rain sometimes as acidic as lemon juice. Acid rain didn't just kill fish, it also damaged trees and crops and even began to dissolve limestone buildings.

You'll be glad to hear that the acid rain problem today is much less serious than it was in the 1960s. Power plants have reduced their emissions by switching to low-sulfur coal and installing scrubbers in their smokestacks. But they didn't do this out of the goodness of their hearts; they did it in response to government

policy. Without such intervention, power companies would have had no incentive to take the environmental effects of their actions into account.

When individuals impose costs on or provide benefits for others but don't have an incentive to take those costs and benefits into account, economists say that the situation includes *externalities*. You may recall that we briefly noted this phenomenon in Chapters 1, 6, and 13. There we stated that principal sources of market failure are actions that create *side effects* that are not



credit: tk

For many polluters, acid rain is someone else's problem.

What you will learn in this chapter:

- ▶ What **externalities** are and why they can lead to inefficiency in a market economy and support for government intervention
- ▶ The difference between **negative** and **positive externalities**
- ▶ The importance of the **Coase theorem**, which explains how private individuals can sometimes solve externalities
- ▶ Why some government policies to deal with externalities, such as **emissions taxes**, **tradable permits**, or **Pigouvian subsidies**, are efficient, although others, like **environmental standards**, are inefficient
- ▶ How positive externalities give rise to arguments for **industrial policy**

properly taken into account—that is, externalities. In this chapter, we’ll examine the economics of externalities, seeing how they can get in the way of economic efficiency and cause markets to fail, why they provide a reason for government intervention in markets, and how economic analysis can be used to guide government policy.

Because externalities arise from the side effects of actions, we need to study them from two slightly different vantage points. First, we consider the situation in which the side effect—that is pollution—can be directly observed and quantified. Whenever an activity can be directly observed and quantified, it can be regulated: by imposing direct controls on it, by taxing it, or by subsidizing it. As we will see, government intervention in this case should be aimed

directly at moving the market to the right quantity of the side effect. But in many situations, only the original activity, not its side effect, can be observed. For example, we can’t observe the congestion or pollution caused by a single car; so the government is unable to implement policies that control the side effect directly. What it can do is employ policies that affect the *original* activity—driving. So in the second part of our analysis we will consider how governments can indirectly achieve the right quantity of the side effect through influencing the activity that generates it. In a fundamental way, however, the two approaches are equivalent: each one involves, at the margin, setting the benefit of doing a little more of something equal to the cost of doing that little bit more.

The Economics of Pollution

Pollution is a bad thing. Yet most pollution is a side effect of activities that provide us with good things: our air is polluted by power plants generating the electricity that lights our cities, and our rivers are damaged by fertilizer runoff from farms that grow our food. Why don’t we accept a certain amount of pollution as the cost of a good life?

Actually, we do. Even highly committed environmentalists don’t think that we can or should completely eliminate pollution—even an environmentally conscious society would accept *some* pollution as the cost of producing useful goods and services. What environmentalists argue is that unless there is a strong and effective environmental policy, our society will generate *too much* pollution—too much of a bad thing. And the great majority of economists agree.

To see why, we need a framework that lets us think about how much pollution a society *should* have; we’ll then be able to see why a market economy, left to itself, will produce more pollution than it should. We’ll start by adopting the simplest framework to study the problem—assuming that the amount of pollution emitted by a polluter is directly observable and controllable.

Costs and Benefits of Pollution

How much pollution should society allow? We learned in Chapter 7 that “how-much” decisions always involve comparing the marginal benefit from an additional unit of something with the marginal cost of that additional unit. The same is true of pollution.

The **marginal social cost of pollution** is the additional cost imposed on society as a whole by an additional unit of pollution. For example, acid rain damages fisheries, crops, and forests, and each additional ton of sulfur dioxide released into the atmosphere increases the damage.

The **marginal social cost of pollution** is the additional cost imposed on society as a whole by an additional unit of pollution.

PITFALLS

SO HOW DO YOU MEASURE THE MARGINAL SOCIAL COST OF POLLUTION?

It might be confusing to think of marginal *social* cost—after all, we have up to this point always defined marginal cost in terms of an individual or a firm, not society as a whole. But it is easily understandable once we link it to the familiar concept of willingness to pay: the marginal social cost of pollution is equal to the *highest willingness to pay among all members of society* to avoid a unit of pollution. But calculating the true cost to society of pollution—marginal or average—is another matter, requiring a great deal of scientific knowledge, as the Economics in Action on page 471 illustrates. As a result, society often underestimates the true marginal social cost of pollution.

The **marginal social benefit of pollution**—the additional gain to society from an additional unit of pollution—may seem like a confusing concept. What’s good about pollution? However, avoiding pollution requires using scarce resources that could have been used to produce other goods and services. For example, to reduce the quantity of sulfur dioxide they emit, power companies must either buy expensive low-sulfur coal or install special scrubbers to remove sulfur from their exhaust. The more sulfur dioxide they are allowed to emit, the lower these extra costs. Suppose that we can calculate how much money the power industry would save if it were allowed to emit an additional ton of sulfur dioxide. That saving is the marginal benefit to society of emitting an extra ton of sulfur dioxide.

Using hypothetical numbers, Figure 19-1 shows how we can determine the **socially optimal quantity of pollution**—the quantity of pollution society would choose if all its costs and benefits are fully accounted for. The upward-sloping marginal social cost curve, *MSC*, shows how the marginal cost to society of an additional ton of sulfur dioxide varies with the quantity of emissions. (An upward slope is likely because natural self-cleaning processes can often handle low levels of pollution but are overwhelmed when pollution reaches high levels.) The marginal social benefit curve, *MSB*, is downward sloping because it is progressively harder, and therefore more expensive, to achieve a further reduction in pollution as the total amount of pollution falls. In other words, the cost to a power plant of reducing pollution to zero is very high indeed.

The socially optimal quantity of pollution in this example isn’t zero. It’s Q_{OPT} , the level corresponding to point *O*, where *MSB* crosses *MSC*. At Q_{OPT} , the marginal social benefit from an additional ton of emissions and its marginal social cost are equalized at \$200.

But will a market economy, left to itself, arrive at the socially optimal quantity of pollution? No, it won’t.

The **marginal social benefit of pollution** is the additional gain to society as a whole from an additional unit of pollution.

The **socially optimal quantity of pollution** is the quantity of pollution that society would choose if all the costs and benefits of pollution were fully accounted for.

PITFALLS

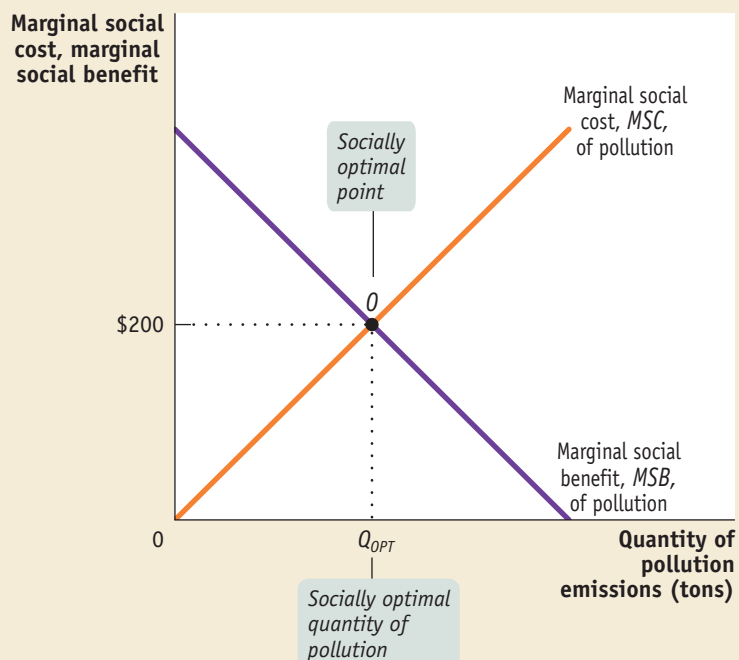
SO HOW DO YOU MEASURE THE MARGINAL SOCIAL BENEFIT OF POLLUTION?

Similar to the problem of measuring the marginal social cost of pollution, the concept of willingness to pay helps us understand the marginal social benefit of pollution in contrast to the marginal benefit to an individual or firm. It’s simply equal to the highest willingness to pay for the right to emit a unit of pollution across all producers. But unlike the marginal social cost of pollution, the value of the marginal social benefit of pollution is a number likely to be known—to polluters, that is.

Figure 19-1

The Socially Optimal Quantity of Pollution

Pollution yields both costs and benefits. Here the curve *MSC* shows how the marginal cost to society as a whole from emitting one more ton of sulfur dioxide depends on the quantity of sulfur dioxide emissions. The curve *MSB* shows how the marginal benefit to society as a whole of emitting an additional ton of sulfur dioxide depends on the quantity of emissions. The socially optimal quantity of pollution is Q_{OPT} ; at that quantity, the marginal social benefit of pollution is equal to the marginal social cost, corresponding to \$200.



Pollution: An External Cost

Pollution yields both benefits and costs to society. But in a market economy without government intervention, those who benefit from pollution—like the owners of power companies—decide how much pollution occurs. They have no incentive to take into account the costs of pollution that they impose on others.

To see why, remember the nature of the benefits and costs from pollution. For polluters, the benefits take the form of monetary savings: by emitting an extra ton of sulfur dioxide, any given polluter saves the cost of buying expensive, low-sulfur coal or installing pollution-control equipment. So the benefits of pollution accrue directly to the polluters.

The costs of pollution, though, fall on people who have no say in the decision about how much pollution takes place: people who fish in northeastern lakes do not control the decisions of power plants.

Figure 19-2 shows the result of this asymmetry between who reaps the benefits and who pays the costs. In a market economy without government intervention to protect the environment, only the benefits of pollution are taken into account in choosing the quantity of pollution. So the quantity of emissions won't be at the socially optimal level Q_{OPT} ; it will be Q_{MKT} , the level at which the marginal social benefit of an additional ton of pollution is zero, but the marginal social cost of that additional ton is much larger—\$400. The quantity of pollution in a market economy without government intervention will be higher than its socially optimal level. (The Pigouvian tax noted in Figure 19-2 will be explained shortly.)

The reason is that in the absence of government intervention, those who derive the benefits from pollution—in this case, the owners of power plants—don't have to compensate those who bear the costs. So the marginal cost of pollution to any given polluter is zero: polluters have no incentive to limit the amount of emissions. For example, before the Clean Air Act of 1970, midwestern power plants used the cheapest type of coal available, regardless of how much pollution it caused, and did nothing to scrub their emissions.

The environmental costs of pollution are the best-known and most important example of an **external cost**—an uncompensated cost that an individual or firm

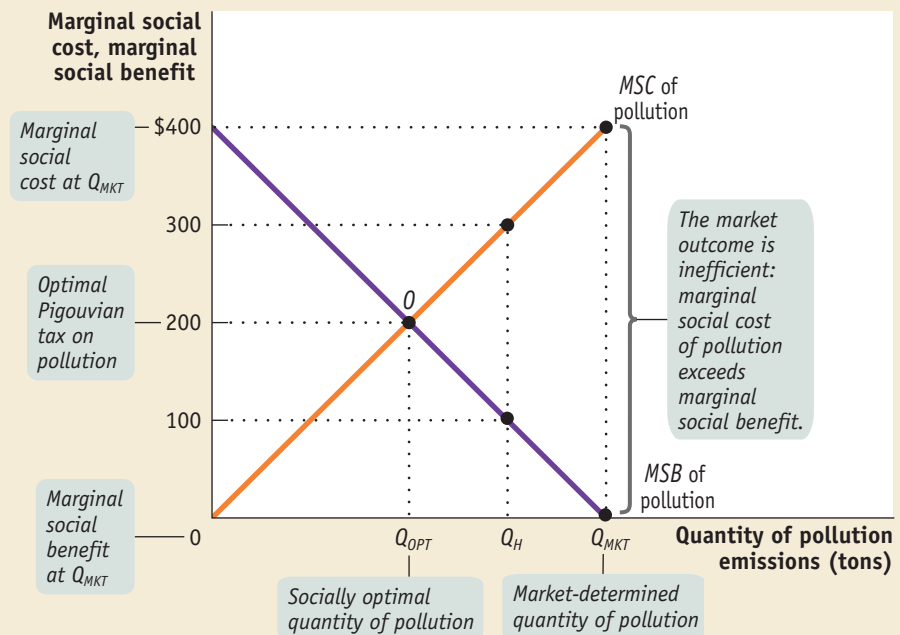
An **external cost** is an uncompensated cost that an individual or firm imposes on others.

Figure 19-2

Why a Market Economy Produces Too Much Pollution

In the absence of government intervention, the quantity of pollution will be Q_{MKT} , the level at which the marginal social benefit of pollution to polluters is zero. This is an inefficiently high quantity of pollution: the marginal social cost, \$400, greatly exceeds the marginal social benefit, \$0. An optimal Pigouvian tax of \$200, the value of the marginal social cost of pollution when it equals the marginal social benefit of pollution, can move the market to the socially optimal quantity of pollution, Q_{OPT} .

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FOR INQUIRING MINDS

TALKING AND DRIVING

Why is that guy in the car in front of us driving so erratically? Is he drunk? No, he's talking on his cell phone.

Traffic safety experts take the risks posed by driving while talking very seriously. Using hands-free, voice-activated phones doesn't seem to help much because the main danger is distraction. As one traffic safety consultant put it, "It's not where your eyes are; it's where your head is." And we're not talking about a trivial problem.

One estimate suggests that people who talk on their cell phones while driving may be responsible for 600 or more traffic deaths each year.

The National Safety Council urges people not to use phones while driving. But a growing



"It's not where your eyes are, it's where your head is."

taking that call is worth the cost, you aren't taking into account the cost to other people. Driving while talking, in other words, generates a serious—sometimes fatal—negative externality.

number of people say that voluntary standards aren't enough; they want the use of cell phones while driving made illegal, as it already is in Japan, Israel, and several other countries.

Why not leave the decision up to the driver? Because the risk posed by driving while talking isn't just a risk to the driver; it's also a risk to others—especially people in other cars. Even if you decide that the benefit to you of

imposes on others. There are many other examples of external costs besides pollution. Probably the most important, and certainly the most familiar, is traffic congestion—an individual who chooses to drive during rush hour increases congestion and so increases the travel time of other drivers.

We'll see later in this chapter that there are also important examples of **external benefits**, benefits that individuals or firms confer on others without receiving compensation. External costs and benefits are jointly known as **externalities**, with external costs called **negative externalities** and external benefits called **positive externalities**.

As we've already suggested, externalities can lead to individual decisions that are not optimal for society as a whole. Let's take a closer look at why, focusing on the case of pollution.

The Inefficiency of Excess Pollution

We have just shown that in the absence of government action, the quantity of pollution will be *inefficient*: polluters will pollute up to the point at which the marginal social benefit of pollution is zero, as shown by the pollution quantity Q_{MKT} in Figure 19-2. Recall that an economic outcome is inefficient if some people could be made better off without making others worse off. In Chapter 6 we showed why the market equilibrium quantity in a perfectly competitive market is the quantity that maximizes total surplus. Here, we can use a variation of that analysis to show why the market equilibrium quantity Q_{MKT} is an inefficient quantity of pollution.

Because the marginal social benefit of pollution is zero at Q_{MKT} , reducing the quantity of pollution by one ton would add very little to the total social benefit from pollution. Meanwhile, we see in Figure 19-2 that the marginal social cost of an additional ton of pollution at Q_{MKT} is quite high—\$400. This means that reducing the

An **external benefit** is a benefit that an individual or firm confers on others without receiving compensation.

External benefits and costs are known as **externalities**; external costs are **negative externalities**, and external benefits are **positive externalities**.

quantity of pollution by one ton would reduce the total social cost of pollution by \$400, with a negligible effect on total benefits. So total surplus rises by approximately \$400 if the quantity of pollution falls by one ton.

If the quantity of pollution is reduced further, there will be more gains in total surplus, though they will be smaller. For example, if the quantity of pollution is Q_H , the marginal social benefit of a ton of pollution is \$100, but the marginal social cost is still \$300. This means that reducing the quantity of pollution by one ton leads to a net gain in total surplus of approximately $\$300 - \$100 = \$200$. This tells us that Q_H is still an inefficiently high quantity of pollution. Only if the quantity of pollution is reduced to Q_{OPT} , where the marginal cost and the marginal benefit of an additional ton of pollution are both \$200, is the outcome efficient.

Private Solutions to Externalities

Can the private sector solve the problem of externalities without government intervention? Bear in mind that when an outcome is inefficient, there is potentially a deal that could make people better off. Why don't individuals find a way to make that deal?

In an influential 1960 article, the economist Ronald Coase pointed out that in an ideal world the private sector could indeed deal with all externalities. According to the **Coase theorem**, even in the presence of externalities an economy can always reach an efficient solution provided that the costs of making a deal are sufficiently low. The costs of making a deal are known as **transaction costs**.

To get a sense of Coase's argument, imagine two neighbors, Mick and Britney, who both like to barbecue in their backyards on summer afternoons. Mick likes to play golden oldies on his boombox while barbecuing; but this annoys Britney, who can't stand that kind of music.

Who prevails? You might think that it depends on the legal rights involved in the case: if the law says that Mick has the right to play whatever music he wants, Britney just has to suffer; if the law says that Mick needs Britney's consent to play music in his backyard, Mick has to live without his favorite music while barbecuing.

But as Coase pointed out, the outcome need not be determined by legal rights, because Britney and Mick can make a private deal. Even if Mick has the right to play his music, Britney could pay him not to. Even if Mick can't play the music without an OK from Britney, he can offer to pay her to give that OK. These payments allow them to reach an efficient solution, regardless of who has the legal upper hand. If the benefit of the music to Mick exceeds its cost to Britney, the music will go on; if the benefit to Mick is less than the cost to Britney, there will be silence.

The implication of Coase's analysis is that externalities need not lead to inefficiency because individuals have an incentive to find a way to make mutually beneficial deals that lead them to take externalities into account when making decisions. When individuals *do* take externalities into account, economists say that they **internalize the externality**. If externalities are fully internalized, the outcome is efficient even without government intervention.

Why can't individuals always internalize externalities? Our barbecue example assumes that Mick and Britney are able to get together and make a deal. In many situations involving externalities, however, transaction costs prevent individuals from making efficient deals. Examples of transaction costs include the following:

- The costs of communication among the interested parties—costs that may be very high if many people are involved
- The costs of making legally binding agreements that may be high if doing so requires the employment of expensive lawyers
- The delays involved in bargaining—even if there is a potentially beneficial deal, both sides may hold out in an effort to extract more favorable terms

According to the **Coase theorem**, even in the presence of externalities an economy can always reach an efficient solution as long as **transaction costs**—the costs to individuals of making a deal—are sufficiently low.

When individuals take external costs or benefits into account, they **internalize the externality**.

Policies Toward Pollution

Before 1970, there were no rules governing the amount of sulfur dioxide power plants in the United States could emit—which is why acid rain got to be such a problem. After 1970, the Clean Air Act set rules about SO_2 emissions—and the acidity of rainfall declined. Economists argued, however, that a more flexible system of rules that exploited the effectiveness of markets could achieve lower pollution at less cost. In 1990 this theory was put into effect with a modified version of the Clean Air Act. And guess what? The economists were right!

In this section we'll look at the policies governments use to deal with pollution and at how economic analysis has been used to improve those policies.

Environmental Standards

The most serious external costs in the modern world are surely those associated with actions that damage the environment—air pollution, water pollution, habitat destruction, and so on. Protection of the environment has become a major role of government in all advanced nations. In the United States, the Environmental Protection Agency is the principal enforcer of environmental policies at the national level, supported by the actions of state and local governments.

How does a country protect its environment? At present the main policy tools are **environmental standards**, rules that protect the environment by specifying actions by producers and consumers. A familiar example is the law that requires almost all vehicles to have catalytic converters, which reduce the emission of chemicals that can cause smog and lead to health problems. Other rules require cities to treat their sewage, factories to avoid or limit certain kinds of pollution, and so on.

Environmental standards came into widespread use in the 1960s and 1970s, and they have had considerable success in reducing pollution. For example, since the United States passed the Clean Air Act in 1970, overall emission of pollutants into the air has fallen by more than a third, even though the population has grown by a third and the size of the economy has more than doubled. Even in Los Angeles, still famous for its smog, the air has improved dramatically: in 1988 ozone levels in the South Coast Air Basin exceeded federal standards on 178 days; in 2003, on only 68 days.

Despite these successes, economists believe that when regulators can control a polluter's emissions directly, there are more efficient ways than environmental standards to deal with pollution. By using methods grounded in economic analysis, society can achieve a cleaner environment at lower cost. Most current environmental standards are inflexible and don't allow reductions in pollution to be achieved at minimum cost. For example, Plant A and Plant B might be ordered to reduce pollution by the same percentage, even if their costs of achieving that objective are very different.

How does economic theory suggest that pollution should be directly controlled? There are actually two approaches: taxes and tradable permits. As we'll see, either approach can achieve an efficient outcome.

Emissions Taxes

One way to deal with pollution directly is to charge polluters an **emissions tax**. Emissions taxes are taxes that depend on the amount of pollution a firm produces. For example, power plants might be charged \$200 for every ton of sulfur dioxide they emit.

Look again at Figure 19-2, which shows that the socially optimal quantity of pollution is Q_{OPT} . At that quantity of pollution, the marginal social benefit and marginal social cost of an additional ton of sulfur dioxide are equal at \$200. But in the absence of government intervention, power companies have no incentive to limit pollution to the socially optimal quantity Q_{OPT} ; instead, they will push pollution up to the quantity Q_{MKT} , at which marginal social benefit is zero.

Environmental standards are rules that protect the environment by specifying actions by producers and consumers.

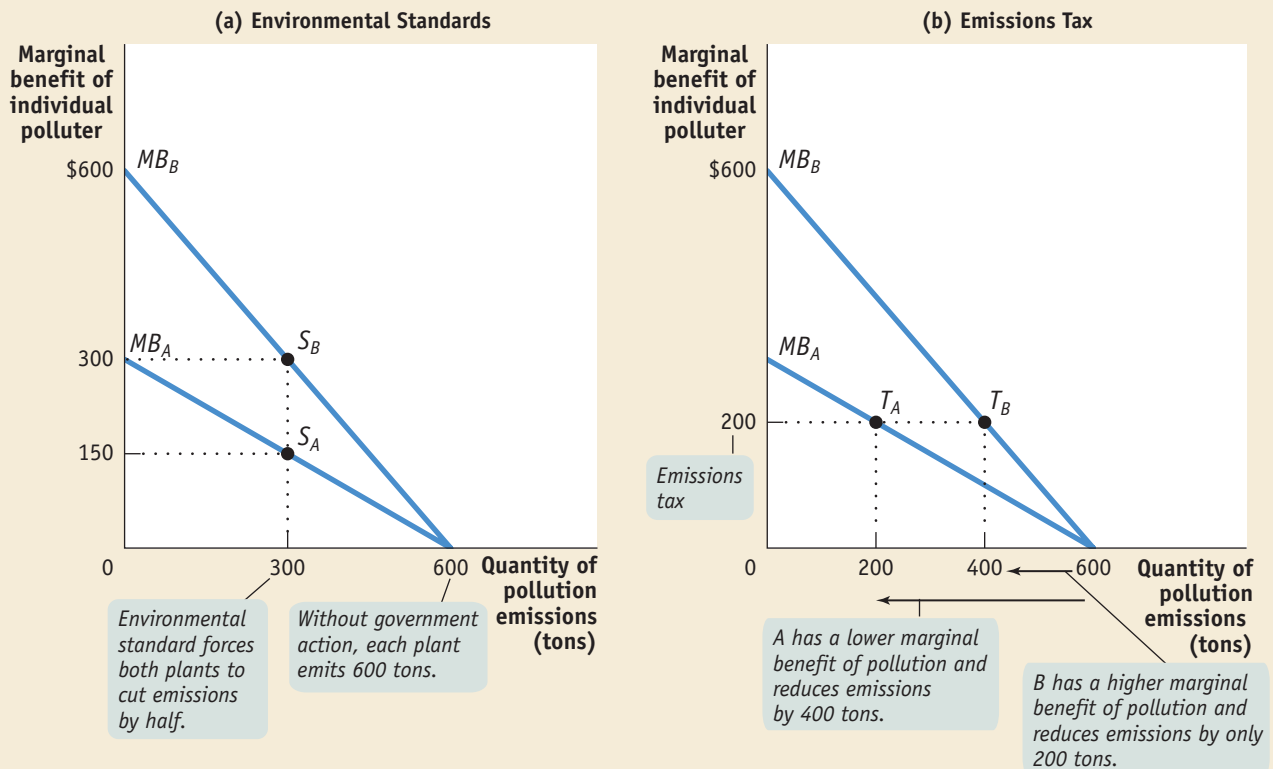
An **emissions tax** is a tax that depends on the amount of pollution a firm produces.

It's now easy to see how an emissions tax can solve the problem. If power companies are required to pay a tax of \$200 per ton of sulfur emitted, they now face a marginal cost of \$200 per ton and have an incentive to reduce emissions to Q_{OPT} tons, the socially optimal level. This illustrates a general result: an emissions tax equal to the marginal social cost at the socially optimal quantity of pollution induces polluters to internalize the externality—to take into account the true costs to society of their actions.

Why is an emissions tax an efficient way to reduce pollution but environmental standards are generally inefficient? Because an emissions tax ensures that the marginal benefit of pollution is equal for all sources of pollution but an environmental standard does not. Figure 19-3 shows a hypothetical industry consisting of only two plants, Plant A and Plant B. We'll assume that Plant A uses newer technology than plant B and so has a lower cost of reducing pollution. Reflecting this difference in costs, Plant A's marginal benefit of pollution curve, MB_A , lies below Plant B's marginal benefit of pollution curve, MB_B . Because it is more costly for Plant B to reduce its pollution, an additional ton of pollution is worth more to Plant B than to Plant A.

In the absence of government action, we know that polluters will pollute until the marginal social benefit of an additional unit of emissions is equal to zero. And since

Figure 19-3 Environmental Standards versus Emissions Taxes



In both panels, MB_A shows the marginal benefit of pollution to Plant A and MB_B shows the marginal benefit of pollution to Plant B. In the absence of government intervention, each plant would emit 600 tons. However, the cost of reducing emissions is lower for Plant A, as shown by the fact that MB_A lies below MB_B . Panel (a) shows the result of an environmental standard that

requires both plants to cut emissions in half; this is inefficient, because it leaves the marginal benefit of pollution higher for Plant B than for Plant A. Panel (b) shows how an emissions tax achieves the same quantity of overall pollution efficiently: faced with an emissions tax of \$200 per ton, both plants reduce pollution to the point where its marginal benefit is \$200. [>web...](#)

the marginal social benefit of pollution is the cost savings, at the margin, to polluters of an additional unit of pollution, this means that without government intervention each plant will pollute until its own marginal cost of pollution is equal to zero. This corresponds to an emissions quantity of 600 tons each for Plants A and B—the quantity of pollution at which MB_A and MB_B are each equal to zero. So although Plant A and Plant B value a ton of emissions differently, without government action they will each choose to emit the same amount of pollution.

Now suppose that the government decides that overall pollution from this industry should be cut in half, from 1,200 tons to 600 tons. Panel (a) of Figure 19-3 shows how this might be achieved with an environmental standard that requires each plant to cut its emissions in half, from 600 to 300 tons. The standard has the desired effect of reducing overall emissions from 1,200 to 600 tons but accomplishes it in an inefficient way. As you can see from panel (a), the environmental standard leads Plant A to produce at point S_A , where its marginal benefit of pollution is \$150, but Plant B produces at point S_B , where its marginal benefit of pollution is twice as high, \$300.

This difference in marginal benefits between the two plants tells us that the same quantity of pollution can be achieved at lower total cost by allowing Plant B to pollute more than 300 tons but inducing Plant A to pollute less. In fact, the efficient way to reduce pollution is to ensure that the marginal benefit of pollution is the same for all plants. When each plant values a unit of pollution equally, there is no way to rearrange pollution reduction among the various plants that achieves the optimal quantity of pollution at a lower total cost.

We can see from panel (b) how an emissions tax achieves exactly that result. Suppose both Plant A and Plant B pay an emissions tax of \$200 per ton, so that the marginal cost of an additional ton of emissions to each plant is now \$200 rather than zero. As a result, Plant A produces at T_A and Plant B produces at T_B . So Plant A reduces its pollution more than it would under an inflexible environmental standard, cutting its emissions from 600 to 200 tons; meanwhile, Plant B reduces its pollution less, going from 600 to 400 tons. In the end, total pollution—600 tons—is the same as under the environmental standard, but total surplus is higher. That's because the reduction in pollution has been achieved efficiently, allocating most of the reduction to Plant A, the plant that can reduce emissions at lower cost.

The term *emissions tax* may convey the misleading impression that taxes are a solution to only one kind of external cost, pollution. In fact, taxes can be used to discourage any activity that generates negative externalities, such as driving during rush hour or operating a noisy bar in a residential area. In general, taxes designed to reduce external costs are known as **Pigouvian taxes**, after the economist A. C. Pigou, who emphasized their usefulness in a classic 1920 book, *The Economics of Welfare*. In our example, the optimal Pigouvian tax is \$200; as you can see from Figure 19-1, this corresponds to the marginal social cost of pollution at the optimal output quantity, Q_{OPT} .

Are there any problems with emissions taxes? The main concern is that in practice government officials usually aren't sure how high the tax should be set. If they set the tax too low, there will be too little improvement in the environment; if they set it too high, emissions will be reduced by more than is efficient. This uncertainty cannot be eliminated, but the nature of the risks can be changed by using an alternative strategy, issuing emissions permits.

Tradable Emissions Permits

Tradable emissions permits are licenses to emit limited quantities of pollutants that can be bought and sold by polluters. They are usually issued to polluting firms according to some formula reflecting their history. For example, each power plant might be issued permits equal to 50 percent of its emissions before the system went into effect. The more important point, however, is that these permits are *tradable*: firms are allowed to buy the right to emit extra pollution from other

Taxes designed to reduce external costs are known as **Pigouvian taxes**.

Tradable emissions permits are licenses to emit limited quantities of pollutants that can be bought and sold by polluters.

firms that are willing to cut pollution to less than the quantity specified in the permits they receive. The effect of a tradable permit system is to create a market in rights to pollute.

Just like emissions taxes, tradable permits provide polluters with an incentive to take the marginal social cost of pollution into account. To see why, suppose that the market price of a permit to emit one ton of sulfur dioxide is \$200. Then every plant has an incentive to limit its emissions of sulfur dioxide to the point where the marginal benefit of emissions is \$200. This is obvious for plants that buy rights to pollute: if a plant must pay \$200 for the right to emit an additional ton of sulfur dioxide, it faces the same incentives as a plant facing an emissions tax of \$200 per ton. But it's equally true for plants that have more permits than they plan to use: by *not* emitting a ton of sulfur dioxide, a plant frees up a permit that it can sell for \$200, so the opportunity cost of a ton of emissions to the plant's owner is \$200.

In short, tradable emissions permits have the same advantage as emissions taxes over environmental standards: either system ensures that those who can reduce pollution most cheaply are the ones who do so. The socially optimal quantity of pollution shown in Figure 19-2 could be efficiently achieved either way: by imposing an emissions tax of \$200 per ton of pollution or by issuing tradable permits to emit Q_{OPT} tons of pollution. But it's important to realize that emissions taxes and tradable permits do more than induce polluting industries to reduce their output. They also provide incentives to create and use less-polluting technology. In fact, the main effect of the permit system for sulfur dioxide has been to change *how* electricity is produced rather than to reduce the nation's electricity output. For example, power companies have shifted to the use of alternative fuels such as low-sulfur coal and natural gas; they have also installed scrubbers that take much of the sulfur dioxide out of a power plant's emissions.

The main problem with tradable emissions permits is the flip-side of the problem with emissions taxes: because it is difficult to determine the optimal quantity of pollution, governments can find themselves issuing either too many permits—that is, they don't reduce pollution enough—or too few—that is, they reduce pollution too much.

In practice, after first relying on rigid environmental standards, the U.S. government has turned to a system of tradable emissions permits to control acid rain, and current proposals would extend that system to other major sources of pollution. The Economics in Action that follows describes how the system has worked in practice.

economics in action

Controlling Acid Rain

The Clean Air Act of 1970 instituted what even the Environmental Protection Agency (EPA) calls a “command-and-control” regime, in which businesses and individuals were given detailed instructions about what to do to reduce air pollution. When the act was revised in 1990, however, the EPA made an effort to move in the direction of market-based remedies. The most notable of these is the program designed to reduce sulfur dioxide emissions from electric power plants, which are a major source of acid rain.

The sulfur dioxide program issues “allowances” to power plants based on their historical consumption of coal. Each allowance is the right to emit one ton of sulfur dioxide during or after a specified year. Power companies are free to buy or sell allowances. However, they must present the EPA with enough allowances to cover their own emissions. So plants with extra allowances can sell them, but plants without enough allowances must buy the difference.

Since the program began in 1994, the price per allowance has fluctuated, sometimes going below \$100 and sometimes above \$200; in 2004 it was \$260. This is well below

>> QUICK REVIEW

- ▶ Governments often limit pollution with *environmental standards*. Generally such standards are inefficient because they are inflexible.
- ▶ When the quantity of pollution emitted can be directly observed and controlled, environmental goals can be achieved efficiently in two ways: *emissions taxes* and *tradable emissions permits*. These methods are efficient because they are flexible, allocating more pollution reduction to those who can do it more cheaply.
- ▶ An emissions tax is a form of *Pigouvian tax*, a tax designed to reduce external costs. The optimal Pigouvian tax is equal to the marginal social cost of pollution at the socially optimal quantity of pollution.

the price most analysts expected, and some environmentalists have taken the low price as a sign that the government should seek further reductions in pollution levels.

Economists who have analyzed the system believe it has led to large savings compared with what would have been the costs of achieving the same quantity of pollution under a regulatory rule that did not allow the power companies to trade. ■

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>> CHECK YOUR UNDERSTANDING 19-2

1. Some opponents of tradable emissions permits object to them on the grounds that polluters that sell their permits benefit monetarily from their contribution to polluting the environment. Assess this argument.
2. Explain the following:
 - a. Why an emissions tax smaller than or greater than the external cost of pollution is inefficient
 - b. Why a system of tradable emissions permits that sets the total quantity of allowable pollution too high or too low is inefficient

Solutions appear at back of book.

Production, Consumption, and Externalities

Nobody imposes external costs like pollution out of malice. Pollution, traffic congestion, and other harmful externalities are side effects of activities, like electricity generation or driving, that are otherwise desirable. We've just learned how government regulators can move the market to the socially optimal quantity when the side effect can be directly controlled. But as we cautioned earlier, in some cases it's not possible to directly control the side effect; only the original activity can be influenced. As we'll see shortly, government policies in these situations must instead be geared to changing the quantity of the original activity, which in turn changes the quantity of the side effect produced.

This approach, although slightly more complicated, has several advantages. First, it gives us a clear understanding of how the quantity of the original, desirable activity is altered by policies designed to manage its side effects (which will, in fact, typically occur both when the side effect can be directly controlled and when it can't). Second, it lets us evaluate arguments against environmental policy—arguments that arise from the fact that desirable activities are unavoidably impeded by policies intended to control their side effects. Finally, it helps us think about a phenomenon that is different but related to the problem of external costs: what should be done when an activity generates external *benefits*.

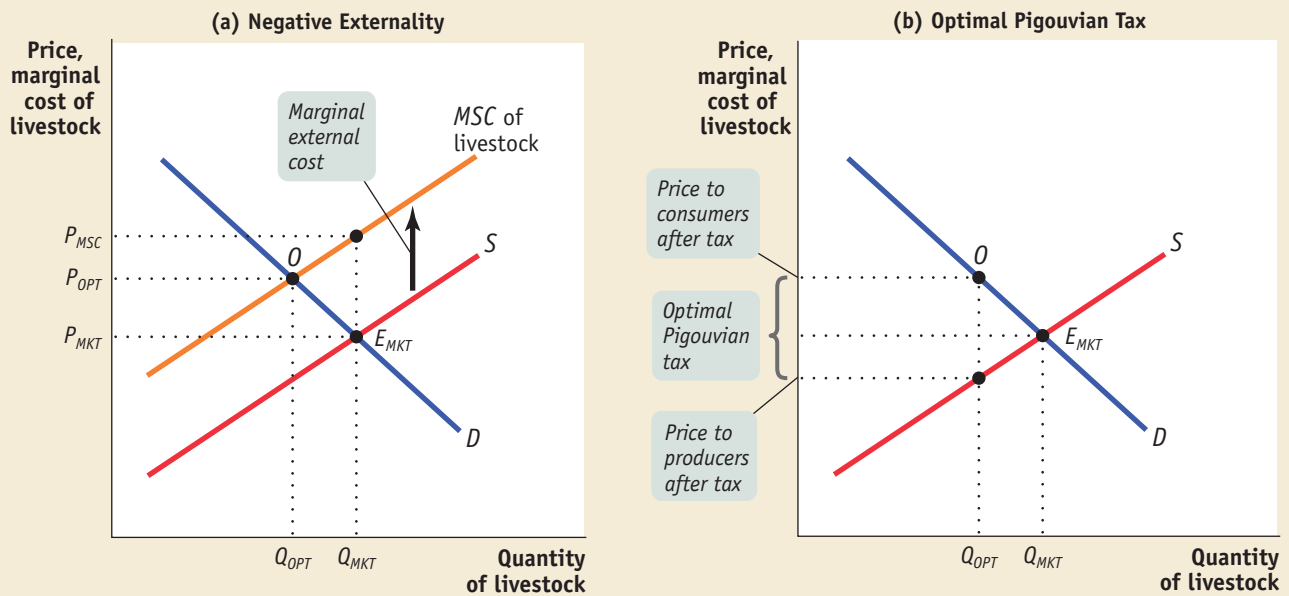
Private versus Social Costs

Given current technology, there is no affordable way to breed and raise livestock on a commercial scale without hurting the environment. Whatever it is—cows, pigs, chicken, sheep, or salmon—livestock farming produces prodigious amounts of what is euphemistically known as “muck.” But that's not all: scientists estimate that the amount of methane gas produced by livestock (the same gas produced when a person—heaven forbid!—belches) currently rivals the pollution caused by the burning of fossil fuels in the creation of greenhouse gases. From the point of view of society as a whole, then, the cost of livestock farming includes both direct production costs to the farmer (payments for factors of production and inputs such as animal feed) and the external environmental costs imposed as a by-product. In the absence of government intervention, however, livestock farmers have no incentive to take into account the environmental costs of their production decisions. As a result, in the absence of government intervention, livestock farmers will produce too much output.



credit line

Muck and methane gas: the costly side-effects of producing a side of bacon.

Figure 19-4 Negative Externalities and Production

Livestock production generates external costs, so the marginal social cost curve of livestock, MSC , corresponds to the supply curve, S , shifted upward by the marginal external cost. Panel (a) shows that without government action, the market produces the amount Q_{MKT} . It is greater than the socially optimal quantity of livestock production, Q_{OPT} , the quantity at which MSC crosses the demand

curve, D . At Q_{MKT} , the market price, P_{MKT} , is less than P_{SC} , the true marginal cost to society of livestock production. Panel (b) shows how an optimal Pigouvian tax on livestock production, equal to its marginal external cost, moves the production to Q_{OPT} , resulting in lower output and a higher price to consumers. [>web...](#)

Panel (a) of Figure 19-4 illustrates this point. The demand curve for livestock by consumers is represented by the market demand curve D ; the market, or industry, supply curve is given by the curve S . In the absence of government intervention, market equilibrium will be at point E_{MKT} , yielding the amount produced and consumed Q_{MKT} and the market price P_{MKT} . At that point, the marginal benefit to society of another unit of livestock (measured by the market price) is equal to the marginal cost incurred by the industry for producing that unit.

Let's look a little more closely at the supply curve. Assuming that the livestock industry is competitive, we know from Chapter 9 that the industry supply curve corresponds to the horizontal sum of all the individual supply curves of producers in the industry. In addition, we know that each individual producer's supply curve corresponds to its marginal cost curve. Putting these two facts together implies that the industry supply curve arises from the horizontal sum of the individual producers' marginal cost curves: a given point on S corresponds to the total industry-wide marginal cost at the corresponding output level. But we also know from our earlier discussion that this estimation of marginal cost does not include the external cost that production imposes on others. In other words, when external costs are present, the industry supply curve does not reflect the true cost to society of production of the good.

In order to account for the true cost to society of an additional unit of the good, we must define the **marginal social cost of a good or activity**, which is equal to the marginal cost of production plus the marginal external cost generated by an additional unit of the good or activity. It captures the increase in production cost to the industry *and* the increase in external cost to the rest of society caused by producing one more unit. Panel (a) of Figure 19-4 shows the marginal social cost of livestock

The **marginal social cost of a good or activity** is equal to the marginal cost of production plus its marginal external cost.

production curve, MSC ; it corresponds to the industry supply curve *shifted upward* by the amount of the marginal external cost. With the marginal social cost curve and the demand curve, we can find the socially optimal quantity of a good or activity that creates external costs: it is the output quantity Q_{OPT} , the output level corresponding to O , the point at which MSC and D cross. Reflecting the proper accounting for external cost, Q_{OPT} is less than Q_{MKT} . So left to its own, a market will result in too much of a good that carries external costs being produced and consumed. Correspondingly, without government action, the price to consumers of such a good is too low: at the output level Q_{MKT} , the unregulated market price P_{MKT} is lower than P_{SC} , the true marginal cost to society of a unit of livestock.

Environmental Policy, Revisited

We have already seen two efficient methods for controlling pollution when government regulators can control it directly: an emissions tax and a system of tradable emissions permits. Are there similar methods that lead to an efficient quantity of pollution when regulators can target only the original activity or good, such as livestock production? Yes, there are—although they will take the form of a tax on livestock sales or a license to produce a unit of livestock rather than on the pollution created. These methods will move the market to the efficient quantity by compelling producers to internalize the externality caused by livestock production in their decisions.

Consider first the case of a Pigouvian tax on livestock transactions. Once such a tax is in effect, the cost to a livestock farmer of producing an additional unit of livestock includes both the marginal cost of production and the tax. If the tax is set at the right amount, it is exactly equal to the marginal external cost. As shown in panel (b) of Figure 19-4, the optimal Pigouvian tax will move the market outcome to the optimal point O .

A system of tradable permits that restricts the industry-wide quantity of livestock produced to the optimal level has the same effect. Suppose that in order to produce an additional unit of livestock, a farmer must purchase a permit. The cost of this permit behaves like a Pigouvian tax, and once again external costs are completely internalized in the private decisions of producers.

So Q_{OPT} , the efficient quantity of livestock produced and consumed, corresponds to the efficient quantity of pollution generated by livestock production. You might ask yourself at this point how this analysis, in terms of the optimal amount of a good that gives rise to an external cost, relates to our earlier analysis of the optimal amount of pollution. Except for the effect that emissions taxes and tradable emissions permits have on the creation and adoption of less-polluting production methods, the two approaches are equivalent: the difference between the two comes down to a matter of units. The first analysis was carried out in units of pollution and the second in units of a good that yields pollution. But regardless of the framework we use, the underlying method is the same: to find the level at which society's marginal benefit from another unit equals society's marginal cost.

But our second analysis does create additional insights: we see how consumption choices are affected by policies designed to counteract external costs. Note that in panel (b) of Figure 19-4, consumers consume less livestock (in the form of meat purchased at supermarkets and restaurants) and pay a higher market price at the socially optimal quantity. (We know from Chapter 5 that exactly how the burden of the tax is allocated between producers and consumers depends on the price elasticities of demand and supply.) Moreover, this shows us that criticisms of environmental policies made exclusively on the basis that they “hurt consumers” are misguided.

Finally, you might ask which method a regulator would choose if a choice existed between policies that target pollution directly and policies that target production of the original good. Generally, whenever feasible it is a good idea to target the pollution directly. The main reason, as we mentioned earlier, is that it gives incentives for

the creation and adoption of less-polluting production methods. This, in turn, lessens the disincentive to produce the goods that people really want that arises when the good is targeted.

As this book goes to press, an example of this phenomenon is being reported. A Florida-based company, Agcert, has developed technology whereby methane from pig-waste tanks can be drawn off and either burnt or used as “biofuel” to generate electricity. The company claims that this technology can achieve an average emissions reduction of one ton of methane gas per pig per year, a sizable savings in an industry where farms can have as many as 10,000 animals. Farmers could then be granted “credits” for their emissions reductions, which they could then sell to producers in other industries who want to purchase a license to pollute. Such credits could be a lucrative source of income for farmers, given that the current market price for a one-ton credit for emissions is around \$7 to \$8. Agcert is currently valued at around \$128 million. As some have commented, this invention has given new life to an old saying among plumbers and sewer workers: “Where there’s muck, there’s gold.”

Private versus Social Benefits

Not all externalities are negative. In some important cases, an economic activity creates external benefits—that is, individual actions provide benefits to other people for which the producers are not compensated.

The most important source of external benefits in the modern economy probably involves creation of knowledge. In high-tech industries like semiconductors, innovations by one firm are quickly emulated and improved upon both by rival firms in the same industry and by firms in other industries. Such spreading of knowledge among individuals and firms is known as a **technology spillover**. Such spillovers often take place through face-to-face contact. As Economics in Action on page 471 explains, bars and restaurants in California’s Silicon Valley are famed for their technical gossip, and the need to keep tabs on the latest innovations is a major reason so many high-tech firms are clustered near each other.

We’ll discuss the economics of knowledge creation in Chapter 22. For now, let’s just look at the implications of external benefits in general for economic efficiency and economic policy. Suppose that the production of some good—say, semiconductor chips—yields positive externalities. How does this affect our analysis of the chip market, and does it create a justification for government intervention?

Just as external costs cause the marginal social *cost* of producing a good to exceed the industry’s marginal cost, when there are external benefits from a good, the marginal social *benefit* exceeds consumers’ marginal benefit. This is illustrated in panel (a) of Figure 19-5 (page 470), which shows the market for semiconductor chips. Since there are no external costs in this case, the industry supply curve, S , represents the true marginal social cost to society of production. The demand curve, D , represents the marginal benefit that accrues to *consumers of the good*: each point on the demand curve corresponds to the willingness to pay of the last consumer to purchase the good at the corresponding price. But it does not incorporate the benefits to society as a whole from production of the good—the technological spillover an additional unit provides to the economy as a whole.

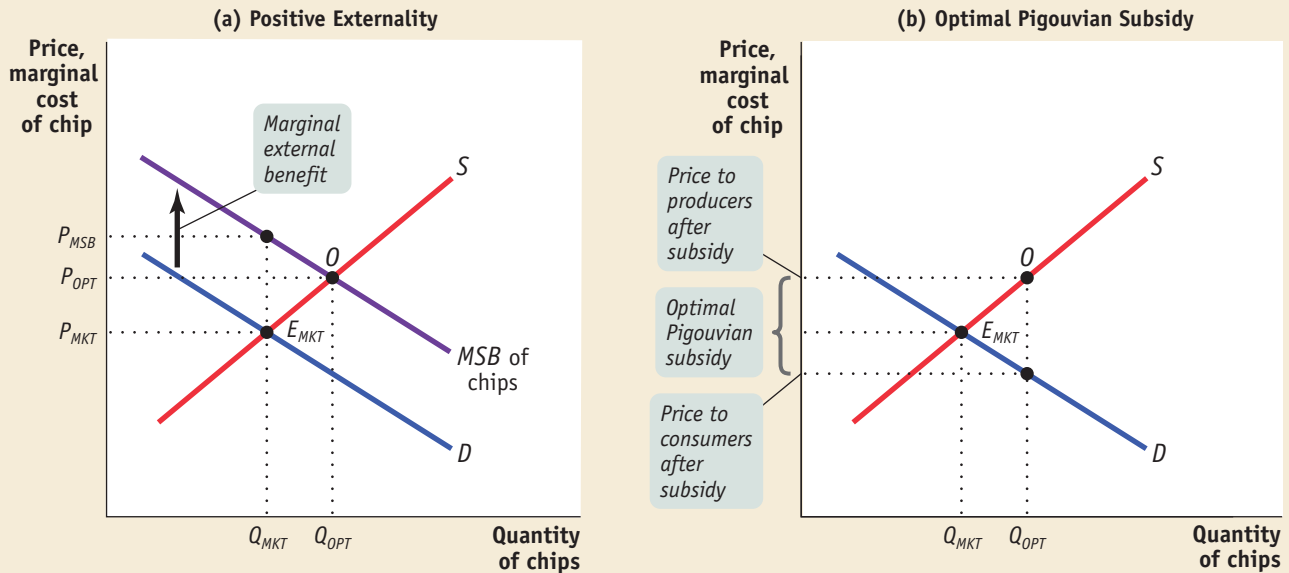
To explore this phenomenon we need a new concept, the **marginal social benefit of a good or activity**—the marginal benefit that accrues to consumers from an additional unit of the good or activity, plus the marginal external benefit to society from an additional unit. As you can see from panel (a) of Figure 19-5, the marginal social benefit curve, MSB , corresponds to the demand curve D shifted upward by the amount of the marginal external benefit.

The analysis in this case is very similar to that of external costs. Left to itself, the market will reach an equilibrium at E_{MKT} , the point at which the demand curve D crosses the supply curve S at a market price P_{MKT} . But the quantity of output at this

A **technology spillover** is an external benefit that results when knowledge spreads among individuals and firms.

The **marginal social benefit of a good or activity** is equal to the marginal benefit that accrues to consumers plus its marginal external benefit.

Figure 19-5 Positive Externalities and Production



Semiconductor chip production generates external benefits, so the marginal social benefit curve of chips, MSB , corresponds to the demand curve, D , shifted upward by the marginal external benefit. Panel (a) shows that without government action, the market produces Q_{MKT} . It is lower than the socially optimal quantity of production, Q_{OPT} , the quantity at which

MSB crosses the supply curve, S . At Q_{MKT} , the market price, P_{MKT} , is less than P_{MSB} , the true marginal benefit to society of semiconductor chip production. Panel (b) shows how an optimal Pigouvian subsidy to chip producers, equal to its marginal external benefit, moves the production to Q_{OPT} , resulting in higher output and a higher price to producers. [>web...](#)

A **Pigouvian subsidy** is a payment designed to encourage activities that yield external benefits.

An **industrial policy** is a policy that supports industries believed to yield positive externalities.

equilibrium, Q_{MKT} , is inefficiently low: at that output level, the marginal social benefit of an additional unit, P_{SB} , exceeds the industry's marginal cost of producing that unit, P_{MKT} . The optimal quantity of production and consumption is Q_{OPT} , the quantity at which marginal cost is equal to marginal social benefit.

How can the economy be induced to produce Q_{OPT} chips? The answer is a **Pigouvian subsidy**: a payment designed to encourage activities that yield external benefits. The optimal Pigouvian subsidy, shown in panel (b) of Figure 19-5, is equal to the marginal external benefit of producing an additional unit. Producers receive the price paid by consumers plus the per-unit subsidy, inducing them to produce more output. Such a subsidy is an example of an **industrial policy**, a general term for a policy of supporting industries believed to yield positive externalities.

Although the strict economic logic supporting such efforts is impeccable, economists are generally less enthusiastic about industrial policies to promote positive externalities than they are about fees and permit schemes to discourage negative externalities. This lack of enthusiasm reflects a mixture of practical and political judgments. First, positive externalities—which most often involve the creation of knowledge and new technologies—are typically much harder to identify and measure than negative externalities. (A simple sensor can keep track of how many tons of sulfur dioxide come out of a smokestack. But how do you tell whether and when a new product embodies a technology that will benefit other producers and consumers?) In addition, producers gain monetarily from subsidies: they receive a higher price than they otherwise would. So many economists also fear, with some historical justification, that a program intended to promote industries that yield positive externalities will degenerate into a program that promotes industries with political pull.

However, there is one activity that is widely believed to generate positive externalities and is provided with considerable subsidies: education!

SUMMARY

- When pollution can be directly observed and controlled, government policies should be geared directly to producing the **socially optimal quantity of pollution**, the quantity at which the **marginal social cost of pollution** is equal to the **marginal social benefit of pollution**. In the absence of government intervention, a market produces too much pollution because polluters take only their benefit from polluting into account, not the costs imposed on others.
- The costs to society of pollution are an example of an **external cost**; in some cases, however, economic activities yield **external benefits**. External costs and benefits are jointly known as **externalities**, with external costs called **negative externalities** and external benefits called **positive externalities**.
- According to the **Coase theorem**, individuals can find a way to **internalize the externalities**, making government intervention unnecessary, as long as **transaction costs**—the costs of making a deal—are sufficiently low. However, in many cases transaction costs are too high to permit such deals.
- Governments often deal with pollution by imposing **environmental standards**, a method, economists argue, that is usually an inefficient way to reduce pollution. Two efficient methods for reducing pollution are **emissions taxes**, a form of **Pigouvian tax**, and **tradable emissions permits**. The optimal Pigouvian tax on pollution is equal to its marginal social cost at the socially optimal quantity of pollution. These methods also provide incentives for the creation and adoption of less-polluting production technologies.
- When only the original good or activity can be controlled, government policies are geared to influencing how much of it is produced. When there are external costs from production, the **marginal social cost of a good or activity** exceeds its marginal cost to producers, the difference being the marginal external cost. Without government action, the market produces too much of the good or activity. The optimal Pigouvian tax on production of the good or activity is equal to its marginal external cost, yielding lower output and a higher price to consumers.
- When a good or activity yields external benefits, such as **technology spillovers**, the **marginal social benefit of the good or activity** is equal to the marginal benefit accruing to consumers plus its marginal external benefit. Without government intervention, the market produces too little of the good or activity. An optimal **Pigouvian subsidy** to producers, equal to the marginal external benefit, moves the market to the socially optimal quantity of production. This yields higher output and a higher price to producers. It is a form of **industrial policy**, a policy to support industries that are believed to generate positive externalities. Economists are often skeptical of industrial policies because external benefits are hard to measure and they motivate producers to lobby for lucrative benefits.

KEY TERMS

Marginal social cost of pollution, p. 456
 Marginal social benefit of pollution, p. 457
 Socially optimal quantity of pollution, p. 457
 External cost, p. 458
 External benefit, p. 459
 Externalities, p. 459
 Negative externalities, p. 459

Positive externalities, p. 459
 Coase theorem, p. 460
 Transaction costs, p. 460
 Internalize the externality, p. 460
 Environmental standards, p. 462
 Emissions tax, p. 462
 Pigouvian taxes, p. 464
 Tradable emission permits, p. 464

Marginal social cost of a good or activity, p. 467
 Technology spillover, p. 469
 Marginal social benefit of a good or activity, p. 469
 Pigouvian subsidy, p. 470
 Industrial policy, p. 470

PROBLEMS

- What type of externality (positive or negative) is described in each of the following examples? Is the marginal social benefit greater than, equal to, or less than the marginal benefit to the individual? Is the marginal social cost greater than, equal to, or less than the marginal cost to the individual? Consequently, without intervention, will there be too little or too much (relative to what would be socially optimal) of this activity?
 - Mrs. Chau plants lots of colorful flowers in her front yard.
 - “Anna Crombie and Fritz,” a popular clothing store, opens in a shopping mall, attracting more shoppers to the mall.
 - The fraternity next to your dorm plays loud music through its outside speakers, keeping you from studying.
 - Maija, who lives next to an apple orchard, decides to keep bees to produce honey.
 - Justine buys a large SUV that consumes a lot of gasoline.

2. The loud music coming from the sorority next to your dorm is a negative externality that can be directly quantified. The table below shows the marginal social benefit and the marginal social cost per decibel (dB, a measure of volume) of music.

Volume of music (dB)	Marginal social benefit	Marginal social cost
90		
91	\$36	\$0
92	30	2
93	24	4
94	18	6
95	12	8
96	6	10
97	0	12

- Draw the marginal social benefit curve and the marginal social cost curve. Use your diagram to determine the socially optimal volume of music.
 - The members of the sorority are the only individuals benefiting from the music, and they bear none of the cost of playing music. Which volume of music will they choose to play?
 - The college imposes a Pigouvian tax of \$3 per decibel of music, to be paid by the sorority. From your diagram, determine the volume of music the sorority will now choose to play.
3. Many dairy farmers in California are adopting a new technology that allows them to produce their own electricity from methane gas generated by animal wastes. By capturing the methane and turning it into fuel, this practice reduces the amount of methane gas released into the atmosphere. (One cow can produce up to 2 kilowatts a day.) In addition to reducing their own utility bills, the system allows the farmers to sell any electricity they produce to their electric utility at favorable rates.
- Explain how the ability to earn money from capturing and transforming methane gas behaves like a Pigouvian tax on methane gas pollution and can lead dairy farmers to emit the efficient amount of methane gas pollution.
 - Suppose that dairy farmers differ in their abilities to transform methane into electricity—some have lower costs of transformation than others. Explain how this system leads to an efficient allocation of emissions reduction among dairy farmers.
4. The accompanying table shows the total social benefit from steel production and the total cost to steel producers of producing steel. Producing each ton of steel imposes an external cost of \$60 per ton.

Quantity of steel (tons)	Total social benefit	Total cost
1	\$115	\$10
2	210	30
3	285	60
4	340	100
5	375	150

- Calculate the marginal social benefit per ton of steel and the marginal cost per ton of steel to steel producers. Then calculate the marginal social cost per ton of steel.
 - What is the market equilibrium level of steel production?
 - What is the socially optimal quantity of steel production?
 - If you wanted to impose a Pigouvian tax to remedy the problem created by the negative externality, how high would the Pigouvian tax have to be per ton of steel?
5. Education is an example of a positive externality: acquiring more education not only has benefits for the individual student, but having a more highly educated workforce (more human capital) is good for the economy as a whole. The accompanying table illustrates the marginal benefit to Sian per year of education and the marginal cost per year of education. Each year of education, however, has an external benefit to society equal to \$8,000. Assume that the marginal social production cost is the same as the marginal cost paid by an individual student.

Quantity of education (years)	Sian's marginal benefit of education	Sian's marginal cost of education
9		
10	\$20,000	\$15,000
11	19,000	16,000
12	18,000	17,000
13	17,000	18,000
14	16,000	19,000
15	15,000	20,000
16	14,000	21,000
17	13,000	22,000

- What is the market equilibrium number of years of education for Sian?
- Calculate the marginal social benefit. What is the socially optimal number of years of education?
- You are in charge of determining education funding. If you could use either a Pigouvian tax or a Pigouvian subsidy to induce Sian to choose the socially optimal amount of education, which would you choose? How high would you set this tax or subsidy per year of education?

6. Getting a flu shot reduces not only your chance of getting the flu but also the chance that you will pass it on to someone else.
- Draw a diagram showing the supply curve of inoculating different proportions of the population and the demand curve (which represents the marginal benefit to the patients being inoculated). The supply curve represents the marginal cost per flu shot. Assume that the marginal cost of each flu shot is constant. You can assume that the demand curve is downward sloping.
 - Will the marginal social benefit to society be higher, lower, or the same as the demand curve? Why? Draw the marginal social benefit into your diagram.
 - In your diagram, show the market equilibrium quantity and the socially optimal quantity of flu shots.
 - Is the market equilibrium quantity of flu shots socially efficient? Why or why not?
 - Many university health centers offer free flu shots to students and employees. Does this solution necessarily achieve efficiency? Explain, using your diagram.
7. Draw a diagram of the supply curve (marginal cost incurred by the industry) and demand curve (marginal benefit to households) for telephone service. The marginal cost of connecting another household to the telephone network is increasing, as it is more and more costly to connect another household as the size of the network grows larger. Assume that the demand curve, as usual, is downward sloping.
- Label the market equilibrium in your diagram M .

Telephone service is a positive externality (sometimes called a “network externality”). There is an external benefit to connecting one more household to the telephone network beyond the private benefit to the household that is connected. This external benefit is the benefit for everybody else of being able to call the newly connected household.

- Draw the marginal social benefit curve into your diagram and, assuming that the marginal social cost equals the industry’s marginal cost, find the socially optimal point and label it O .
 - Explain why the market equilibrium E_{MKT} is inefficient.
 - Governments subsidize phone service for rural households. Describe how such a Pigouvian subsidy eliminates the inefficiency.
8. According to a report from the U.S. Census (*Washington Post*, 07/18/2002; A20), “the average [lifetime] earnings of a full-time, year round worker with a high school education are about \$1.2 million compared with \$2.1 million for a college graduate.” This indicates that there is a considerable benefit to a graduate from investing in his or her own education. However, tuition at most state universities covers only about two-thirds to three-quarters of the cost of education. That is, the state applies a Pigouvian subsidy to college education.
- If a Pigouvian subsidy is appropriate, is the externality created by a college education a positive or a negative external-

ty? What does this tell you about the differences between the costs and benefits to students compared to social costs and benefits? What are some reasons for the differences?

- Fishing for sablefish has been so intensive that sablefish were threatened with extinction. After several years of banning such fishing, the government is now proposing to introduce vouchers, each of which entitles its holder to a catch of a certain size, and these vouchers can be traded. Explain how fishing is a negative externality and how the voucher scheme may overcome the inefficiency created by this externality.
- There are two dry-cleaning companies (College Cleaners, Big Green Cleaners) in the small town of Collegetown, and they are a major source of air pollution. Together they currently produce 350 units of air pollution. The town wants to reduce this level of pollution to 200 units. The accompanying table shows the current pollution level produced by each company, along with the marginal cost to that company of reducing its pollution per unit of pollution reduction. The marginal cost is constant.

Companies	Initial pollution level (units of pollution)	Marginal cost of reducing pollution (per unit of pollution)
College Cleaners	230	\$5
Big Green Cleaners	120	\$2

- Suppose that Collegetown were to pass an environmental standards law that limits each company to 100 units of pollution. What would be the total cost to the two companies of each reducing its pollution emissions to 100 units?
- Suppose instead that Collegetown issues 100 pollution vouchers to each company, each entitling the company to one unit of pollution, and that these vouchers can be traded.
- How much is each pollution voucher worth to College Cleaners? to Big Green Cleaners? (That is, how much would each company, at most, be willing to pay for one more voucher?)
 - Who will sell vouchers and who will buy them? How many vouchers will be traded?
 - What is the total cost to the two companies of the pollution controls under this voucher system?
11. Ronald owns a cattle farm at the source of a long river. His cattle’s waste flows into the river, and down many miles to where Carla lives. Carla gets her drinking water from the river. By allowing his cattle’s waste to flow into the river, Ronald imposes a negative externality on Carla. In each of the two following cases, do you think that through negotiation, Ronald and Carla can find an efficient solution? What might this solution look like?
- There are no telephones, and for Carla to talk to Ronald, she has to travel for two days on a rocky road.
 - Carla and Ronald both have e-mail access, making it costless for them to communicate.

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