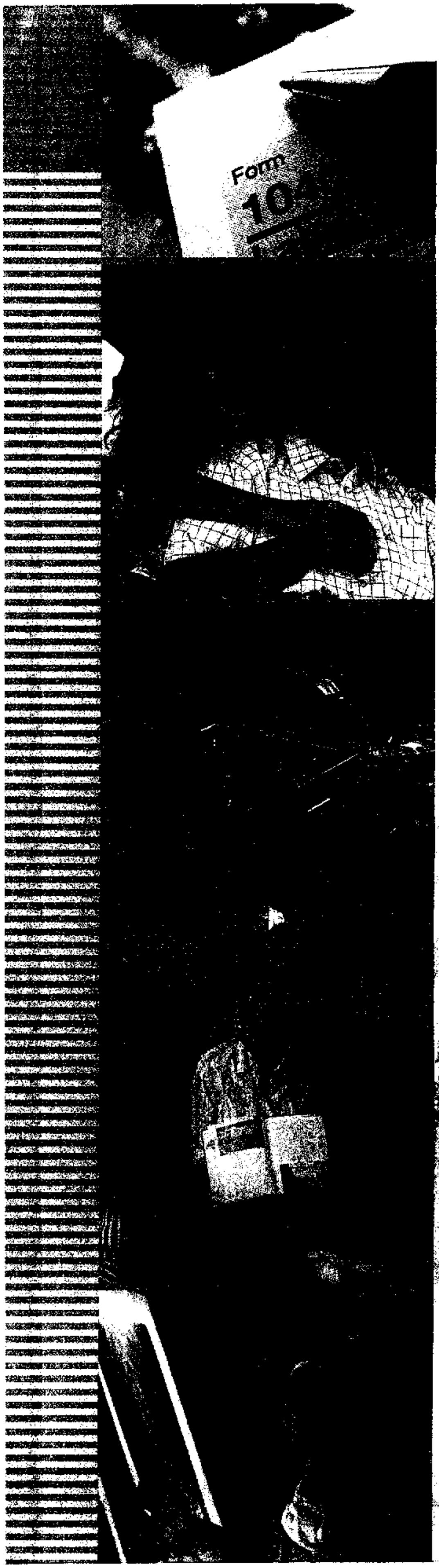


SECOND EDITION

Public Finance and Public Policy

Jonathan Gruber

5 Externalities: Problems and Solutions

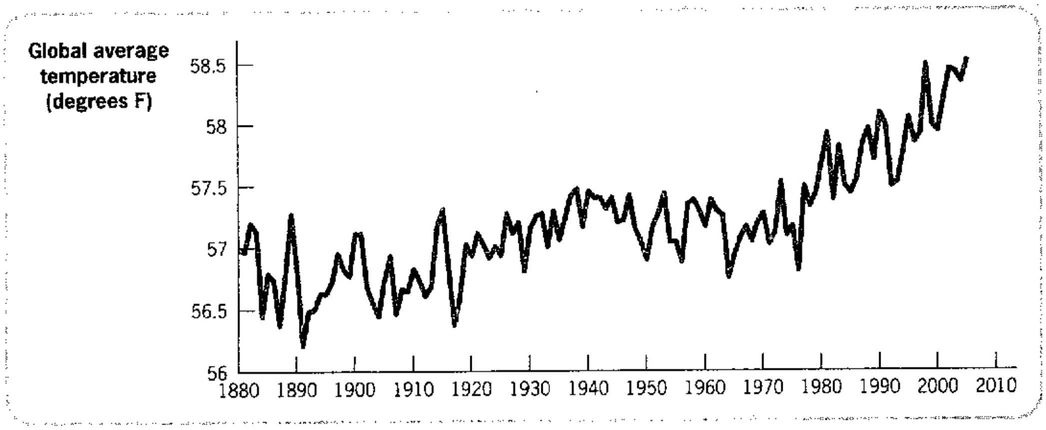
In December 1997, representatives from over 170 nations met in Kyoto, Japan, to attempt one of the most ambitious international negotiations ever: an international pact to limit the emissions of carbon dioxide worldwide. The motivation for this international gathering was increasing concern over the problem of global warming. As Figure 5-1 on p. 116 shows, there has been a steady rise in global temperatures over the twentieth century. A growing scientific consensus suggests that the cause of this warming trend is human activity, in particular the use of fossil fuels. The burning of fossil fuels such as coal, oil, natural gas, and gasoline produces carbon dioxide, which in turn traps the heat from the sun in the earth's atmosphere. Many scientists predict that, over the next century, global temperatures could rise by as much as ten degrees Fahrenheit.[1]

If you are reading this in North Dakota, that may sound like good news. Indeed, for much of the United States, this increase in temperatures will improve agricultural output as well as quality of life. In most areas around the world, however, the impacts of global warming would be unwelcome, and in many cases, disastrous. The global sea level could rise by almost three feet, increasing risks of flooding and submersion of low-lying coastal areas. Some scientists project, for example, that 20–40% of the entire country of Bangladesh will be flooded due to global warming over the next century, with much of this nation being under more than five feet of water![2]

Despite this dire forecast, the nations gathered in Kyoto faced a daunting task. The cost of reducing the use of fossil fuels, particularly in the major industrialized nations, is enormous. Fossil fuels are central to heating our homes, transporting us to our jobs, and lighting our places of work. Replacing these fossil fuels with alternatives would significantly raise the costs of living

[1] International Panel on Climate Change (2001). Global warming is produced not just by carbon dioxide but by other gases, such as methane, as well, but carbon dioxide is the main cause and for ease we use carbon dioxide as shorthand for the full set of "greenhouse gases."
[2] Mirza et al. (2003).

▪ **FIGURE 5-1**



Average Global Temperature, 1880 to 2005 • There was a steady upward trend in global temperatures throughout the twentieth century.

Source: Figure adapted from NASA's Goddard Institute for Space Studies, "Global Annual Mean Surface Air Temperature Change," located at http://www.giss.nasa.gov/data/gistemp/graphs/Fig.A.pdf.

in developed countries. To end the problem of global warming, some predict that we will have to reduce our use of fossil fuels to nineteenth-century (preindustrial) levels. Yet, even to reduce fossil fuel use to the level ultimately mandated by this Kyoto conference (7% below 1990 levels) could cost the United States $1.1 trillion, or about 10% of GDP.[3] Thus, it is perhaps not surprising that the United States has yet to ratify the treaty agreed to at Kyoto.

Global warming due to emissions of fossil fuels is a classic example of what economists call an **externality.** An externality occurs whenever the actions of one party make another party worse or better off, yet the first party neither bears the costs nor receives the benefits of doing so. Thus, when we drive cars in the United States we increase emissions of carbon dioxide, raise world temperatures, and thereby increase the likelihood that in 100 years Bangladesh will be flooded out of existence. Did you know this when you drove to class today? Not unless you are a very interested student of environmental policy. Your enjoyment of your driving experience is in no way diminished by the damage that your emissions are causing.

externality Externalities arise whenever the actions of one party make another party worse or better off, yet the first party neither bears the costs nor receives the benefits of doing so.

Externalities occur in many everyday interactions. Sometimes they are localized and small, such as the impact on your roommate if you play your stereo too loudly or the impact on your neighbors if your dog uses their garden as a bathroom. Externalities also exist on a much larger scale, such as global warming or *acid rain.* When utilities in the Midwest produce electricity using coal, a by-product of that production is the emission of sulfur dioxide and nitrogen oxides into the atmosphere, where they form sulfuric and nitric acids. These acids may fall back to earth hundreds of miles away, in the process

[3] Nordhaus and Boyer (2000), Table 8.6 (updated to 2000 dollars).

destroying trees, causing billions of dollars of property damage, and increasing respiratory problems in the population. Without government intervention, the utilities in the Midwest bear none of the cost for the polluting effects of their production activities.

> **market failure** A problem that causes the market economy to deliver an outcome that does not maximize efficiency.

Externalities are a classic example of the type of **market failures** discussed in Chapter 1. Recall that the most important of our four questions of public finance is *when* is it appropriate for the government to intervene? As we will show in this chapter, externalities present a classic justification for government intervention. Indeed, 135,000 federal employees, or 5% of the federal workforce, are ostensibly charged with dealing with environmental externalities in agencies such as the Environmental Protection Agency and the Department of the Interior.[4]

This chapter begins with a discussion of the nature of externalities. We focus primarily throughout the chapter on environmental externalities, although we briefly discuss other applications as well. We then ask whether government intervention is necessary to combat externalities, and under what conditions the private market may be able to solve the problem. We discuss the set of government tools available to address externalities, comparing their costs and benefits under various assumptions about the markets in which the government is intervening. In the next chapter, we apply these theories to the study of some of the most important externality issues facing the United States and other nations today: acid rain, global warming, and smoking.

5.1 Externality Theory

In this section, we develop the basic theory of externalities. As we emphasize next, externalities can arise either from the production of goods or from their consumption and can be negative (as in the examples discussed above) or positive. We begin with the classic case of a negative production externality.

Economics of Negative Production Externalities

Somewhere in the United States there is a steel plant located next to a river. This plant produces steel products, but it also produces "sludge," a by-product useless to the plant owners. To get rid of this unwanted by-product, the owners build a pipe out the back of the plant and dump the sludge into the river. The sludge produced is directly proportional to the production of steel; each additional unit of steel creates one more unit of sludge as well.

The steel plant is not the only producer using the river, however. Farther downstream is a traditional fishing area where fishermen catch fish for sale to

[4] This estimate is from the U.S. Office of Personnel Management (2006), p. 87, as well as Web pages of agencies and departments.

local restaurants. Since the steel plant has begun dumping sludge into the river, the fishing has become much less profitable because there are many fewer fish left alive to catch.

This scenario is a classic example of what we mean by an externality. The steel plant is exerting a **negative production externality** on the fishermen, since its production adversely affects the well-being of the fishermen but the plant does not compensate the fishermen for their loss.

negative production externality When a firm's production reduces the well-being of others who are not compensated by the firm.

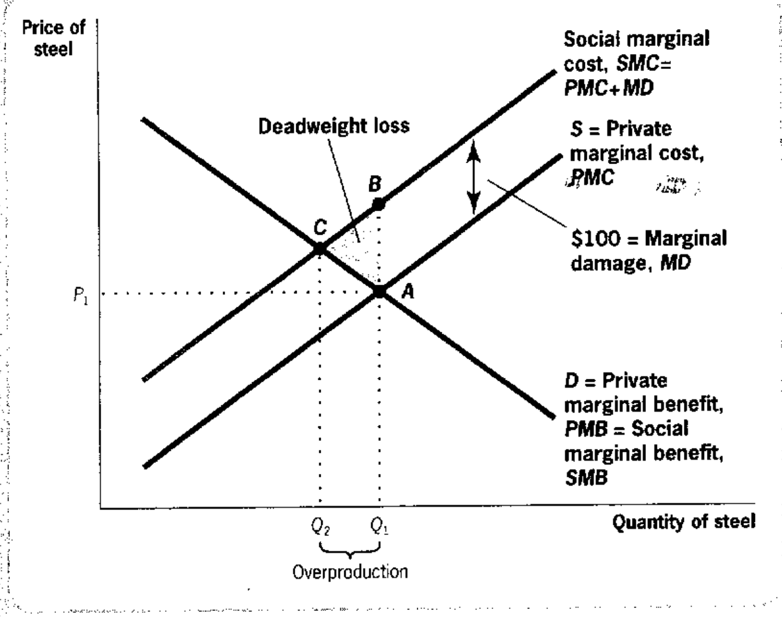
One way to see this externality is to graph the market for the steel produced by this plant (Figure 5-2) and to compare the private benefits and costs of production to the social benefits and costs. *Private benefits and costs* are the benefits and costs borne directly by the actors in the steel market (the producers and consumers of the steel products). *Social benefits and costs* are the private benefits and costs *plus* the benefits and costs to any actors outside this steel market who are affected by the steel plant's production process (the fishermen).

Recall from Chapter 2 that each point on the market supply curve for a good (steel, in our example) represents the market's marginal cost of producing that unit of the good—that is, the **private marginal cost (*PMC*)** of that unit of steel. What determines the welfare consequences of production, however, is the **social marginal cost (*SMC*),** which equals the private marginal cost to the producers of producing that next unit of a good *plus any costs associated with the production of that good that are imposed on others.* This distinction was not made in Chapter 2, because without market failures $SMC = PMC$, the social costs of producing steel are equal to the costs to steel producers.

private marginal cost (*PMC*) The direct cost to producers of producing an additional unit of a good.

social marginal cost (*SMC*) The private marginal cost to producers plus any costs associated with the production of the good that are imposed on others.

■ **FIGURE 5-2**



Market Failure Due to Negative Production Externalities in the Steel Market • A negative production externality of $100 per unit of steel produced (marginal damage, *MD*) leads to a social marginal cost that is above the private marginal cost, and a social optimum quantity (Q_2) that is lower than the competitive market equilibrium quantity (Q_1). There is overproduction of $Q_1 - Q_2$, with an associated deadweight loss of area *BCA*.

Thus, when we computed social welfare in Chapter 2 we did so with reference to the supply curve.

This approach is not correct in the presence of externalities, however. When there are externalities, $SMC = PMC + MD$, where MD is the marginal damage done to others, such as the fishermen, from each unit of production (marginal because it is the damage associated with that particular unit of production, not total production). Suppose, for example, that each unit of steel production creates sludge that kills $100 worth of fish. In Figure 5-2, the SMC curve is therefore the PMC (supply) curve, shifted upward by the marginal damage of $100.[5] That is, at Q_1 units of production (point A), the social marginal cost is the private marginal cost at that point (which is equal to P_1), plus $100 (point B). For every level of production, social costs are $100 higher than private costs, since each unit of production imposes $100 of costs on the fishermen for which they are not compensated.

Recall also from Chapter 2 that each point on the market demand curve for steel represents the sum of individual willingnesses to pay for that unit of steel, or the **private marginal benefit (*PMB*)** of that unit of steel. Once again, however, the welfare consequences of consumption are defined relative to the **social marginal benefit (*SMB*),** which equals the private marginal benefit to the consumers *minus any costs associated with the consumption of the good that are imposed on others.* In our example, there are no such costs imposed by the consumption of steel, so $SMB = PMB$ in Figure 5-2.

private marginal benefit (*PMB*) The direct benefit to consumers of consuming an additional unit of a good by the consumer.

social marginal benefit (*SMB*) The private marginal benefit to consumers plus any costs associated with the consumption of the good that are imposed on others.

In Chapter 2, we showed that the private market competitive equilibrium is at point A in Figure 5-2, with a level of production Q_1 and a price of P_1. We also showed that this was the social-efficiency-maximizing level of consumption for the private market. In the presence of externalities, this relationship no longer holds true. Social efficiency is defined relative to social marginal benefit and cost curves, not to private marginal benefit and cost curves. Because of the negative externality of sludge dumping, the social curves (SMB and SMC) intersect at point C, with a level of consumption Q_2. Since the steel plant owner doesn't account for the fact that each unit of steel production kills fish downstream, the supply curve understates the costs of producing Q_1 to be at point A, rather than at point B. As a result, too much steel is produced ($Q_1 > Q_2$), and the private market equilibrium no longer maximizes social efficiency.

When we move away from the social-efficiency-maximizing quantity, we create a *deadweight loss* for society because units are produced and consumed for which the cost to society (summarized by curve SMC) exceeds the social benefits (summarized by curve $D = SMB$). In our example, the deadweight loss is equal to the area BCA. The width of the deadweight loss triangle is determined by the number of units for which social costs exceed social benefits ($Q_1 - Q_2$). The height of the triangle is the difference between the marginal social cost and the marginal social benefit, the marginal damage.

[5] This example assumes that the damage from each unit of steel production is constant, but in reality the damage can rise or fall as production changes. Whether the damage changes or remains the same affects the shape of the social marginal cost curve, relative to the private marginal cost curve.

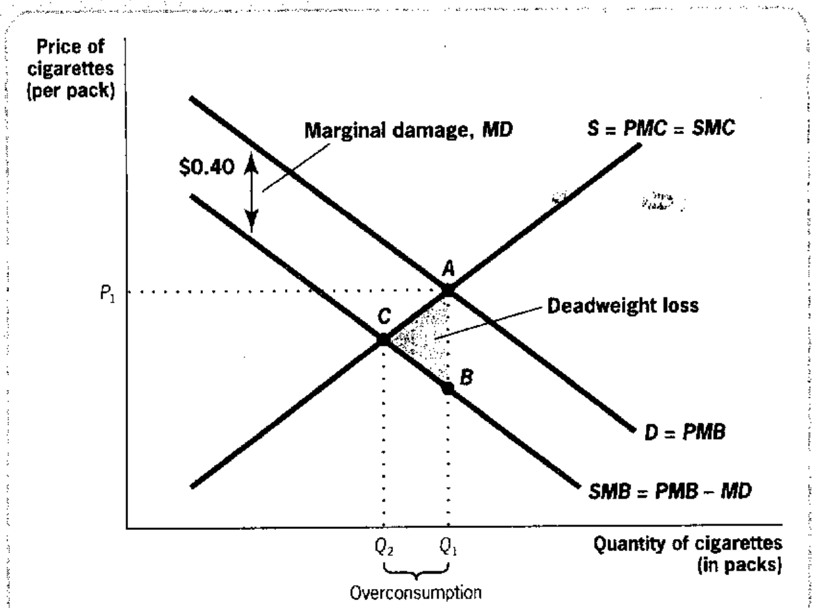
Negative Consumption Externalities

It is important to note that externalities do not arise solely from the production side of a market. Consider the case of cigarette smoke. In a restaurant that allows smoking, your consumption of cigarettes may have a negative effect on my enjoyment of a restaurant meal. Yet you do not in any way pay for this negative effect on me. This is an example of a **negative consumption externality,** whereby consumption of a good reduces the well-being of others, a loss for which they are not compensated. When there is a negative consumption externality, $SMB = PMB - MD$, where MD is the marginal damage done to others by your consumption of that unit. For example, if MD is 40¢ a pack, the marginal damage done to others by your smoking is 40¢ for every pack you smoke.

negative consumption externality When an individual's consumption reduces the well-being of others who are not compensated by the individual.

Figure 5-3 shows supply and demand in the market for cigarettes. The supply and demand curves represent the *PMC* and *PMB*. The private equilibrium is at point *A*, where supply (*PMC*) equals demand (*PMB*), with cigarette consumption of Q_1 and price of P_1. The *SMC* equals the *PMC* because there are no externalities associated with the production of cigarettes in this example. Note, however, that the *SMB* is now below the *PMB* by 40¢ per pack; every pack consumed has a social benefit that is 40¢ below its private benefit. That is, at Q_1 units of production (point *A*), the social marginal benefit is the private marginal benefit at that point (which is equal to P_1), minus 40¢ (point *B*). For each pack of cigarettes, social benefits are 40¢ lower than private benefits, since each pack consumed imposes 40¢ of costs on others for which they are not compensated.

▪ **FIGURE 5-3**



Market Failure Due to Negative Consumption Externalities in the Cigarette Market ▪ A negative consumption externality of 40¢ per pack of cigarettes consumed leads to a social marginal benefit that is below the private marginal benefit, and a social optimum quantity (Q_2) that is lower than the competitive market equilibrium quantity (Q_1). There is overconsumption $Q_1 - Q_2$, with an associated deadweight loss of area *ACB*.

The social-welfare-maximizing level of consumption, Q_2, is identified by point *C*, the point at which *SMB* = *SMC*. There is overconsumption of cigarettes by $Q_1 - Q_2$: the social costs (point *A* on the *SMC* curve) exceed social benefits (on the *SMB* curve) for all units between Q_1 and Q_2. As a result, there is a deadweight loss (area *ACB*) in the market for cigarettes.

▶ APPLICATION

The Externality of SUVs[6]

In 1985, the typical driver sat behind the wheel of a car that weighed about 3,200 pounds, and the largest cars on the road weighed 4,600 pounds. Today, the typical driver is in a car that weighs 4,089 pounds (an increase of 28%) and the largest cars on the road can weigh 8,500 pounds. The major culprits in this evolution of car size are sport utility vehicles (SUVs). The term *SUV* was originally reserved for large vehicles intended for off-road driving, but it now refers to any large passenger vehicle marketed as an SUV, even if it lacks off-road capabilities. SUVs, with an average weight of 4,500 pounds, represented only 6.4% of vehicle sales as recently as 1988, but 17 years later, in 2005, they accounted for over 25% of the new vehicles sold each year.

The consumption of large cars such as SUVs produces three types of negative externalities:

Environmental Externalities The contribution of driving to global warming is directly proportional to the amount of fossil fuel a vehicle requires to travel a mile. The typical compact or mid-size car gets roughly 25 miles to the gallon but the typical SUV gets only 18 miles to the gallon. This means that SUV drivers use more gas to go to work or run their errands, increasing fossil fuel emissions. This increased environmental cost is not paid by those who drive SUVs.

Wear and Tear on Roads Each year, federal, state, and local governments in the United States spend \$33.2 billion repairing our roadways.[7] Damage to roadways comes from many sources, but a major culprit is the passenger vehicle, and the damage it does to the roads is proportional to vehicle weight. When individuals drive SUVs, they increase the cost to government of repairing the roads. SUV drivers bear some of these costs through gasoline taxes (which fund highway repair), since the SUV uses more gas, but it is unclear if these extra taxes are enough to compensate for the extra damage done to roads.

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[6] All data in this application are from the U.S. Environmental Protection Agency (2005) and the U.S. Department of Transportation (2004).

[7] U.S. Department of Transportation (2004), p. 205.

Safety Externalities One major appeal of SUVs is that they provide a feeling of security because they are so much larger than other cars on the road. Offsetting this feeling of security is the added *insecurity* imposed on other cars on the road. For a car of average weight, the odds of having a fatal accident rise by four times if the accident is with a typical SUV and not with a car of the same size. Thus, SUV drivers impose a negative externality on other drivers because they don't compensate those other drivers for the increased risk of a dangerous accident. ◀

Positive Externalities

When economists think about externalities, they tend to focus on negative externalities, but not all externalities are bad. There may also be **positive production externalities** associated with a market, whereby production benefits parties other than the producer and yet the producer is not compensated. Imagine the following scenario: There is public land beneath which there *might* be valuable oil reserves. The government allows any oil developer to drill in those public lands, as long as the government gets some royalties on any oil reserves found. Each dollar the oil developer spends on exploration increases the chances of finding oil reserves. Once found, however, the oil reserves can be tapped by other companies; the initial driller only has the advantage of getting there first. Thus, exploration for oil by one company exerts a *positive production externality* on other companies: each dollar spent on exploration by the first company raises the chance that other companies will have a chance to make money from new oil found on this land.

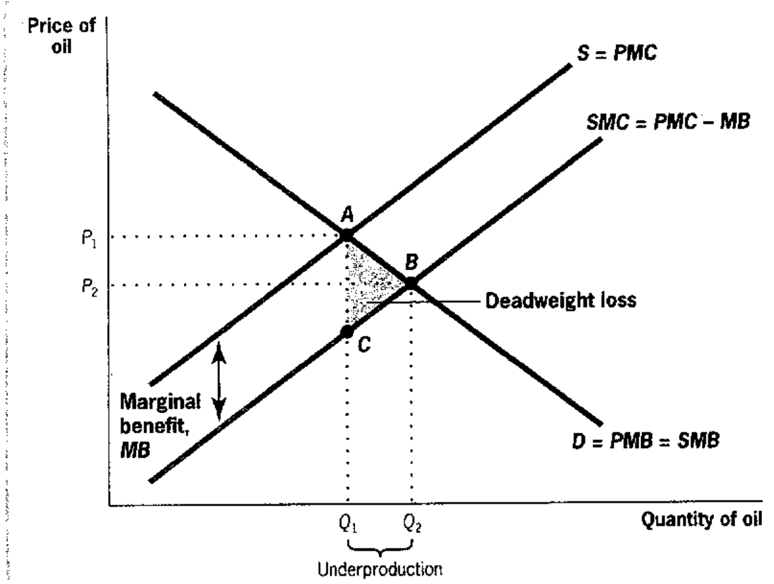
positive production externality When a firm's production increases the well-being of others but the firm is not compensated by those others.

Figure 5-4 shows the market for oil exploration to illustrate the positive externality to exploration: the social marginal cost of exploration is actually *lower* than the private marginal cost because exploration has a positive effect on the future profits of other companies. Assume that the marginal benefit of each dollar of exploration by one company, in terms of raising the expected profits of other companies who drill the same land, is a constant amount *MB*. As a result, the *SMC* is below the *PMC* by the amount *MB*. Thus, the private equilibrium in the exploration market (point *A*, quantity Q_1) leads to *underproduction* relative to the optimal level (point *B*, quantity Q_2) because the initial oil company is not compensated for the benefits it confers on other oil producers.

Note also that there can be **positive consumption externalities.** Imagine, for example, that my neighbor is considering improving the landscaping around his house. The improved landscaping will cost him $1,000, but it is only worth $800 to him. My bedroom faces his house, and I would like to have nicer landscaping to look at. This better view would be worth $300 to me. That is, the total social marginal benefit of the improved landscaping is $1,100, even though the private marginal benefit to my neighbor is only $800. Since this social marginal benefit ($1,100) is larger than the social marginal costs ($1,000), it would be socially efficient for my neighbor to do the landscaping. My neighbor won't do the landscaping, however, since his private

positive consumption externality When an individual's consumption increases the well-being of others but the individual is not compensated by those others.

■ **FIGURE 5-4**



Market Failure Due to Positive Production Externality in the Oil Exploration Market • Expenditures on oil exploration by any company have a positive externality because they offer more profitable opportunities for other companies. This leads to a social marginal cost that is below the private marginal cost, and a social optimum quantity (Q_2) that is greater than the competitive market equilibrium quantity (Q_1). There is underproduction of $Q_2 - Q_1$, with an associated deadweight loss of area *ABC*.

costs ($1,000) exceed his private benefits. His landscaping improvements would have a positive effect on me for which he will not be compensated, thus leading to an underconsumption of landscaping.

Quick Hint One confusing aspect of the graphical analysis of externalities is knowing which curve to shift, and in which direction. To review, there are four possibilities:

- Negative production externality: *SMC* curve lies above *PMC* curve
- Positive production externality: *SMC* curve lies below *PMC* curve
- Negative consumption externality: *SMB* curve lies below *PMB* curve
- Positive consumption externality: *SMB* curve lies above *PMB* curve

Armed with these facts, the key is to assess which category a particular example fits into. This assessment is done in two steps. First, you must assess whether the externality is associated with producing a good or with consuming a good. Then, you must assess whether the externality is positive or negative.

The steel plant example is a negative production externality because the externality is associated with the production of steel, not its consumption; the sludge doesn't come from using steel, but rather from making it. Likewise, our cigarette example is a negative consumption externality because the externality is associated with the consumption of cigarettes; secondhand smoke doesn't come from making cigarettes, it comes from smoking them.

5.2 Private-Sector Solutions to Negative Externalities

In microeconomics, the market is innocent until proven guilty (and, similarly, the government is often guilty until proven innocent!). An excellent application of this principle can be found in a classic work by Ronald Coase, a professor at the Law School at the University of Chicago, who asked in 1960: Why won't the market simply compensate the affected parties for externalities?[8]

The Solution

To see how a market might compensate those affected by the externality, let's look at what would happen if the fishermen owned the river in the steel plant example. They would march up to the steel plant and demand an end to the sludge dumping that was hurting their livelihood. They would have the right to do so because they have *property rights* over the river; their ownership confers to them the ability to control the use of the river.

Suppose for the moment that when this conversation takes place there is no pollution-control technology to reduce the sludge damage; the only way to reduce sludge is to reduce production. So ending sludge dumping would mean shutting down the steel plant. In this case, the steel plant owner might propose a compromise: she would pay the fishermen \$100 for each unit of steel produced, so that they were fully compensated for the damage to their fishing grounds. As long as the steel plant can make a profit with this extra \$100 payment per unit, then this is a better deal for the plant than shutting down, and the fishermen are fully compensated for the damage done to them.

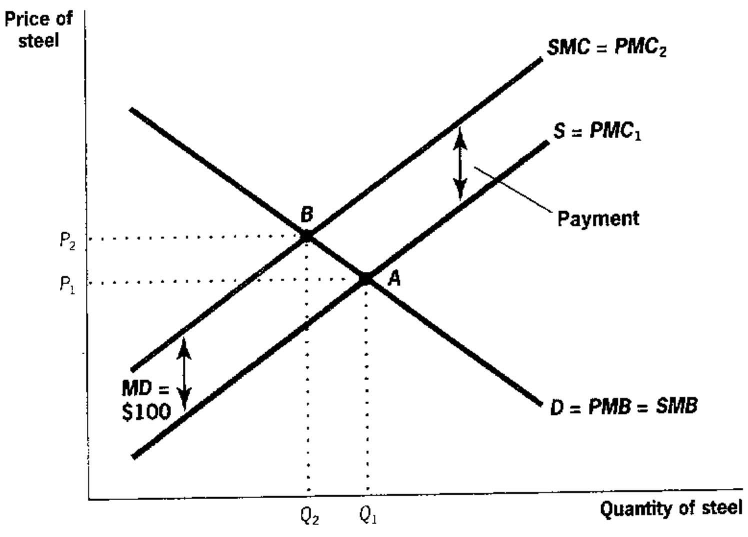
This type of resolution is called **internalizing the externality.** Because the fishermen now have property rights to the river, they have used the market to obtain compensation from the steel plant for its pollution. The fishermen have implicitly created a market for pollution by pricing the bad behavior of the steel plant. From the steel plant's perspective, the damage to the fish becomes just another input cost, since it has to be paid in order to produce.

internalizing the externality When either private negotiations or government action lead the price to the party to fully reflect the external costs or benefits of that party's actions.

This point is illustrated in Figure 5-5. Initially, the steel market is in equilibrium at point *A*, with quantity Q_1 and price P_1, where $PMB = PMC_1$. The socially optimal level of steel production is at point *B*, with quantity Q_2 and price P_2, where $SMB = SMC = PMC_1 + MD$. Because the marginal cost of producing each unit of steel has increased by \$100 (the payment to the fishermen), the private marginal cost curve shifts upward from PMC_1 to PMC_2, which equals *SMC*. That is, social marginal costs are private marginal costs plus \$100, so by adding \$100 to the private marginal costs, we raise the *PMC* to equal the *SMC*. There is no longer overproduction because the social marginal costs and benefits of each unit of production are equalized. This example

[8] For the original paper, see Coase (1960).

■ **FIGURE 5-5**



A Coasian Solution to Negative Production Externalities in the Steel Market • If the fishermen charge the steel plant $100 per unit of steel produced, this increases the plant's private marginal cost curve from PMC_1 to PMC_2, which coincides with the *SMC* curve. The quantity produced falls from Q_1 to Q_2, the socially optimal level of production. The charge internalizes the externality and removes the inefficiency of the negative externality.

Coase Theorem (Part I) When there are well-defined property rights and costless bargaining, then negotiations between the party creating the externality and the party affected by the externality can bring about the socially optimal market quantity.

Coase Theorem (Part II) The efficient solution to an externality does not depend on which party is assigned the property rights, as long as someone is assigned those rights.

illustrates **Part I of the Coase Theorem:** when there are well-defined property rights and costless bargaining, then negotiations between the party creating the externality and the party affected by the externality can bring about the socially optimal market quantity. This theorem states that externalities do not necessarily create market failures, because negotiations between the parties can lead the offending producers (or consumers) to *internalize the externality,* or account for the external effects in their production (or consumption).

The Coase theorem suggests a very particular and limited role for the government in dealing with externalities: establishing property rights. In Coase's view, the fundamental limitation to implementing private-sector solutions to externalities is poorly established property rights. If the government can establish and enforce those property rights, then the private market will do the rest.

The Coase theorem also has an important **Part II:** the efficient solution to an externality does not depend on which party is assigned the property rights, as long as someone is assigned those rights. We can illustrate the intuition behind Part II using the steel plant example. Suppose that the steel plant, rather than the fishermen, owned the river. In this case, the fishermen would have no right to make the plant owner pay a $100 compensation fee for each unit of steel produced. The fishermen, however, would find it in their interest to pay the steel plant to produce less. If the fishermen promised the steel plant owner a payment of $100 for each unit he did not produce, then the steel plant owner would rationally consider there to be an extra $100 cost to each unit he did produce. Remember that in economics, opportunity costs are included in a firm's calculation of costs; thus, forgoing a payment from the fishermen of $100 for each unit of steel not produced has the same effect on production decisions as being forced to pay $100 extra for each unit of steel produced. Once again, the private marginal cost curve would incorporate this extra (opportunity) cost and shift out to the social marginal cost curve, and there would no longer be overproduction of steel.

Quick Hint You may wonder why the fishermen would ever engage in either of these transactions: they receive $100 for each $100 of damage to fish, or pay $100 for each $100 reduction in damage to fish. So what is in it for them? The answer is that this is a convenient shorthand economics modelers use for saying, "The fishermen would charge at least $100 for sludge dumping" or "The fishermen would pay up to $100 to remove sludge dumping." By assuming that the payments are exactly $100, we can conveniently model private and social marginal costs as equal. It may be useful for you to think of the payment to the fishermen as $101 and the payment from the fishermen as $99, so that the fishermen make some money and private and social costs are approximately equal. In reality, the payments to or from the fishermen will depend on the negotiating power and skill of both parties in this transaction, highlighting the importance of the issues raised next.

The Problems with Coasian Solutions

This elegant theory would appear to rescue the standard competitive model from this important cause of market failures and make government intervention unnecessary (other than to ensure property rights). In practice, however, the Coase theorem is unlikely to solve many of the types of externalities that cause market failures. We can see this by considering realistically the problems involved in achieving a "Coasian solution" to the problem of river pollution.

The Assignment Problem The first problem involves assigning blame. Rivers can be very long, and there may be other pollution sources along the way that are doing some of the damage to the fish. The fish may also be dwindling for natural reasons, such as disease or a rise in natural predators. In many cases, it is impossible to assign blame for externalities to one specific entity.

Assigning damage is another side to the assignment problem. We have assumed that the damage was a fixed dollar amount, $100. Where does this figure come from in practice? Can we trust the fishermen to tell us the right amount of damage that they suffer? It would be in their interest in any Coasian negotiation to overstate the damage in order to ensure the largest possible payment. And how will the payment be distributed among the fishermen? When a number of individuals are fishing the same area, it is difficult to say whose catch is most affected by the reduction in the stock of available fish.

The significance of the assignment problem as a barrier to internalizing the externality depends on the nature of the externality. If my loud stereo playing disturbs your studying, then assignment of blame and damages is clear. In the case of global warming, however, how can we assign blame clearly when carbon emissions from any source in the world contribute to this problem? And how can we assign damages clearly when some individuals would like the world to be hotter, while others would not? Because of assignment problems, Coasian solutions are likely to be more effective for small, localized externalities than for larger, more global externalities.

The Holdout Problem Imagine that we have surmounted the assignment problem and that by careful scientific analysis we have determined that each unit of sludge from the steel plant kills $1 worth of fish for each of 100 fishermen, for a total damage of $100 per unit of steel produced.

Now, suppose that the fishermen have property rights to the river, and the steel plant can't produce unless all 100 fishermen say it can. The Coasian solution is that each of the 100 fishermen gets paid $1 per unit of steel production, and the plant continues to produce steel. Each fisherman walks up to the plant and collects his check for $1 per unit. As the last fisherman is walking up, he realizes that he suddenly has been imbued with incredible power: the steel plant cannot produce without his permission since he is a part owner of the river. So, why should he settle for only $1 per unit? Having already paid out $99 per unit, the steel plant would probably be willing to pay more than $1 per unit to remove this last obstacle to their production. Why not ask for $2 per unit? Or even more?

holdout problem Shared ownership of property rights gives each owner power over all the others.

This is an illustration of the **holdout problem,** which can arise when the property rights in question are held by more than one party: the shared property rights give each party power over all others. If the other fishermen are thinking ahead they will realize this might be a problem, and they will all try to be the last one to go to the plant. The result could very well be a breakdown of the negotiations and an inability to negotiate a Coasian solution. As with the assignment problem, the holdout problem would be amplified with a huge externality like global warming, where billions of persons are potentially damaged.

The Free Rider Problem Can we solve the holdout problem by simply assigning the property rights to the side with only one negotiator, in this case the steel plant? Unfortunately, doing so creates a new problem.

Suppose that the steel plant has property rights to the river, and it agrees to reduce production by 1 unit for each $100 received from fishermen. Then the Coasian solution would be for the fishermen to pay $100, and for the plant to then move to the optimal level of production. Suppose that the optimal reduction in steel production (where social marginal benefits and costs are equal) is 100 units, so that each fisherman pays $100 for a total of $10,000, and the plant reduces production by 100 units.

Suppose, once again, that you are the last fisherman to pay. The plant has already received $9,900 to reduce its production, and will reduce its production as a result by 99 units. The 99 units will benefit all fishermen equally since they all share the river. Thus, as a result, if you don't pay your $100, you will still be almost as well off in terms of fishing as if you do. That is, the damage avoided by that last unit of reduction will be shared equally among all 100 fishermen who use the river, yet you will pay the full $100 to buy that last unit of reduction. Thought of that way, why would you pay? This is an example of the **free rider problem:** when an investment has a personal cost but a common benefit, individuals will underinvest. Understanding this incentive, your fellow fishermen will also not pay their $100, and the externality will remain unsolved; if the other fishermen realize that someone is going to grab a free ride, they have little incentive to pay in the first place.

free rider problem When an investment has a personal cost but a common benefit, individuals will underinvest.

Transaction Costs and Negotiating Problems Finally, the Coasian approach ignores the fundamental problem that it is hard to negotiate when there are large numbers of individuals on one or both sides of the negotiation. How can the 100 fishermen effectively get together and figure out how much to charge or pay the steel plant? This problem is amplified for an externality such as global warming, where the potentially divergent interests of billions of parties on one side must be somehow aggregated for a negotiation.

Moreover, these problems can be significant even for the small-scale, localized externalities for which Coase's theory seems best designed. In theory, my neighbor and I can work out an appropriate compensation for my loud music disturbing his studying. In practice, this may be a socially awkward conversation that is more likely to result in tension than in a financial payment. Similarly, if the person next to me in the restaurant is smoking, it would be far outside the norm, and probably considered insulting, to lean over and offer him $5 to stop smoking. Alas, the world does not always operate in the rational way economists wish it would!

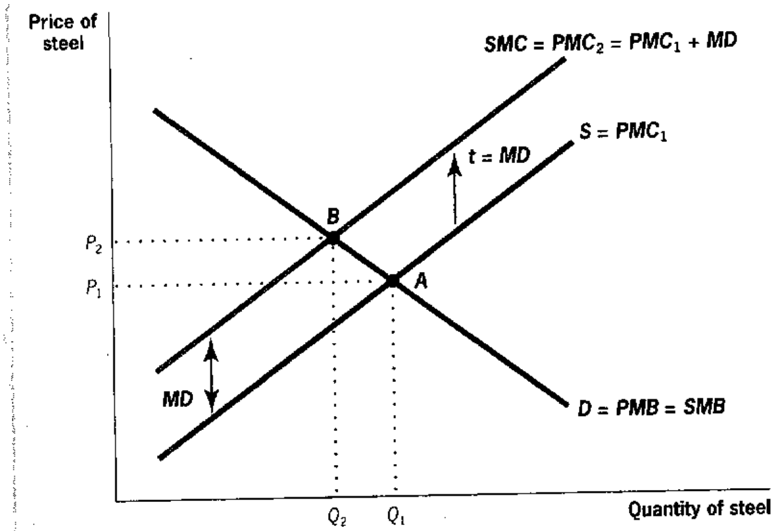
Bottom Line Ronald Coase's insight that externalities can sometimes be internalized was a brilliant one. It provides the competitive market model with a defense against the onslaught of market failures that we will bring to bear on it throughout this course. It is also an excellent reason to suspect that the market may be able to internalize some small-scale, localized externalities. Where it won't help, as we've seen, is with large-scale, global externalities that are the focus of, for example, environmental policy in the United States. The government may therefore have a role to play in addressing larger externalities.

5.3 Public-Sector Remedies for Externalities

In the United States, public policy makers do not think that Coasian solutions are sufficient to deal with large-scale externalities. The Environmental Protection Agency (EPA) was formed in 1970 to provide public-sector solutions to the problems of externalities in the environment. The agency regulates a wide variety of environmental issues, in areas ranging from clean air to clean water to land management.[9]

[9] See http://www.epa.gov/epahome/aboutepa.htm for more information. There are government resources devoted to environmental regulation in other agencies as well, and these resources don't include the millions of hours of work by the private sector in complying with environmental regulation.

■ FIGURE 5-6



Taxation as a Solution to Negative Production Externalities in the Steel Market • A tax of $100 per unit (equal to the marginal damage of pollution) increases the firm's private marginal cost curve from PMC_1 to PMC_2, which coincides with the SMC curve. The quantity produced falls from Q_1 to Q_2, the socially optimal level of production. Just as with the Coasian payment, this tax internalizes the externality and removes the inefficiency of the negative externality.

Public policy makers employ three types of remedies to resolve the problems associated with negative externalities.

Corrective Taxation

We have seen that the Coasian goal of "internalizing the externality" may be difficult to achieve in practice in the private market. The government can achieve this same outcome in a straightforward way, however, by taxing the steel producer an amount MD for each unit of steel produced.

Figure 5-6 illustrates the impact of such a tax. The steel market is initially in equilibrium at point A, where supply ($=PMC_1$) equals demand ($= PMB = SMB$), and Q_1 units of steel are produced at price P_1. Given the externality with a cost of MD, the socially optimal production is at point B, where social marginal costs and benefits are equal. Suppose that the government levies a tax per unit of steel produced at an amount $t = MD$. This tax would act as another input cost for the steel producer, and would shift its private marginal cost up by MD for each unit produced. This will result in a new PMC curve, PMC_2, which is identical to the SMC curve. As a result, the tax effectively internalizes the externality and leads to the socially optimal outcome (point B, quantity Q_2). The government per-unit tax on steel production acts in the same way as if the fishermen owned the river. This type of corrective taxation is often called "Pigouvian taxation," after the economist A. C. Pigou, who first suggested this approach to solving externalities.[10]

[10] See, for example, Pigou (1947).

Subsidies

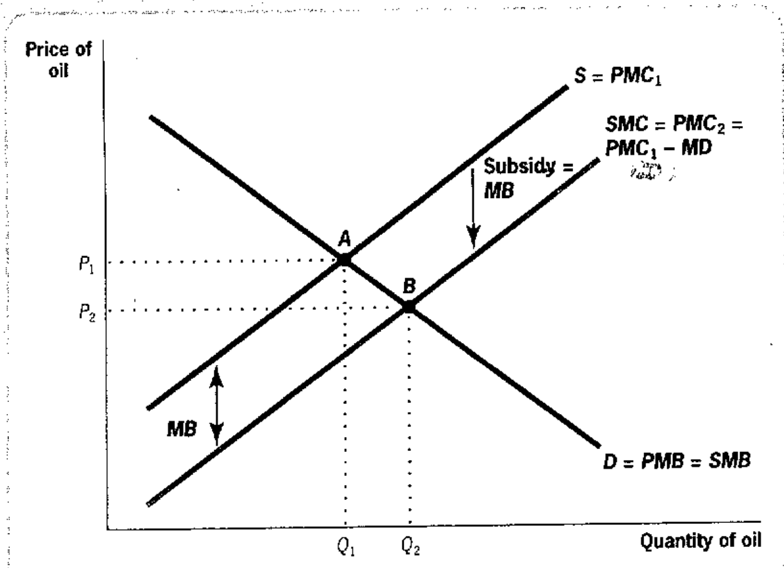
As noted earlier, not all externalities are negative; in cases such as oil exploration or nice landscaping by your neighbors, externalities can be positive.

The Coasian solution to cases such as the oil exploration case would be for the other oil producers to take up a collection to pay the initial driller to search for more oil reserves (thus giving them the chance to make more money from any oil that is found). But, as we discussed, this may not be feasible. The government can achieve the same outcome by making a payment, or a **subsidy,** to the initial driller to search for more oil. The amount of this subsidy would exactly equal the benefit to the other oil companies and would cause the initial driller to search for more oil, since his cost per barrel has been lowered.

subsidy Government payment to an individual or firm that lowers the cost of consumption or production, respectively.

The impact of such a subsidy is illustrated in Figure 5-7, which shows once again the market for oil exploration. The market is initially in equilibrium at point *A* where PMC_1 equals *PMB*, and Q_1 barrels of oil are produced at price P_1. Given the positive externality with a benefit of *MB*, the socially optimal production is at point *B*, where social marginal costs and benefits are equal. Suppose that the government pays a subsidy per barrel of oil produced of $S = MB$. The subsidy would lower the private marginal cost of oil production, shifting the private marginal cost curve down by *MB* for each unit produced. This will result in a new *PMC* curve, PMC_2, which is identical to the *SMC* curve. The subsidy has caused the initial driller to internalize the positive externality, and the market moves from a situation of underproduction to one of optimal production.

▪ **FIGURE 5-7**



Subsidies as a Solution to Positive Production Externalities in the Market for Oil Exploration • A subsidy that is equal to the marginal benefit from oil exploration reduces the oil producer's marginal cost curve from PMC_1 to PMC_2, which coincides with the *SMC* curve. The quantity produced rises from Q_1 to Q_2, the socially optimal level of production.

Regulation

Throughout this discussion, you may have been asking yourself: Why this fascination with prices, taxes, and subsidies? If the government knows where the socially optimal level of production is, why doesn't it just mandate that production take place at that level, and forget about trying to give private actors incentives to produce at the optimal point? Using Figure 5-6 as an example, why not just mandate a level of steel production of Q_2 and be done with it?

In an ideal world, Pigouvian taxation and regulation would be identical. Because regulation appears much more straightforward, however, it has been the traditional choice for addressing environmental externalities in the United States and around the world. When the U.S. government wanted to reduce emissions of sulfur dioxide (SO_2) in the 1970s, for example, it did so by putting a limit or cap on the amount of sulfur dioxide that producers could emit, not by a tax on emissions. In 1987, when the nations of the world wanted to phase out the use of chlorofluorocarbons (CFCs), which were damaging the ozone layer, they banned the use of CFCs rather than impose a large tax on products that used CFCs.

Given this governmental preference for quantity regulation, why are economists so keen on taxes and subsidies? In practice, there are complications that may make taxes a more effective means of addressing externalities. In the next section, we discuss two of the most important complications. In doing so, we illustrate the reasons that policy makers might prefer regulation, or the "quantity approach" in some situations, and taxation, or the "price approach" in others.

APPLICATION

Taxes and Regulation in Practice: The Case of the Baltic Sea[11]

The Baltic Sea is the world's largest brackish sea, a mixture of salt and fresh water. Considered a healthy ecosystem until the 1950s, the Baltic is now one of the most polluted bodies of water on earth. The pollution comes now largely from the former communist countries of Eastern Europe, whose inefficient industries and municipalities continue to send pollutants into the sea and the areas that surround and drain into it. Chemical plants in Poland release toxins into nearby soil, while the Russian city of St. Petersburg sends its untreated sewage directly into the Neva River, which in turn flows to the Baltic. The Western European nations are, however, not blameless. Swedish agriculture uses harmful fertilizers that leach into the Baltic's waters, and highly polluting factories in various Western European nations, though now largely closed, were responsible for some of the chemicals that remain in the sea to this day.

This pollution threatens human health, because some species of fish caught in the Baltic Sea now contain dangerously high levels of dioxin, a cancer-causing substance released when plastics and fuels are burned. Moreover, it also

[11] Helsinki Commission (2003).

weakens the viability of the local fishing industry on which the livelihoods of many Baltic Sea residents depend. Thus, this is a classic negative externality.

The fall of communism in 1989 opened up possibilities for international cooperation that the countries of the Baltic region were quick to exploit. In 1990, Sweden coordinated the creation of the Baltic Sea Joint Comprehensive Environmental Action Programme (JCP), an agreement to begin a massive cleanup effort among 14 nations close to the Baltic Sea. The JCP identified 132 hot spots, particularly large sources of pollution, and agreed to spend about $1 billion a year for 20 years to clean them up. Funding comes from the wealthier parties to the agreement, as well as from international institutions like the World Bank and European Union. The agreement thus allowed wealthier countries like Sweden and Finland to begin protecting their fishing industries and gave poorer countries funds to modernize industrial and municipal systems.

After the agreement was signed, a further set of questions arose. When trying to clean up a pollution hot spot, should governments use regulation (like forbidding the dumping of untreated sewage) or taxation (a charge per unit of sewage dumped)? Under the JCP, as it turns out, both regulation and taxation have been used, often simultaneously. Some examples:

- Poland recently succeeded in having 10 hot spots wiped off the list by quintupling (since 1990) investment in technology for environmental protection. Poland spent hundreds of millions of dollars ensuring that the vast majority of its industrial and municipal wastewater was being treated before entering the Baltic system. Surprisingly, only 6% of these funds came from external sources. The remaining 94% was raised by Poland itself, in the form of fines and fees levied on domestic polluters. A tax on pollution was thus being used to fund compliance with regulations demanding the treatment of wastewater.
- The Swedish city of Käppala now runs its own treatment plant through which industrial and municipal wastewater must flow before entering the Baltic system. Industries are forbidden from discharging wastewater that is corrosive or toxic (regulation) and are charged a fee by the city for the volume of wastewater and for each kilogram of pollutant present in the water sent to the treatment plant (taxation). The fees, which range from $0.50 to $10 per kilogram depending on the pollutant, reflect the cost to the city of treating the water.
- In 2002, the JCP was asked to develop ways of dealing with particular hot spots in Ukraine and Belarus that had arisen because of overloaded and obsolete wastewater treatment systems. The JCP noted that most European countries levy significant charges for water usage on households and industry. Belarus and Ukraine charge only $0.02 per cubic meter of water used, much less than other countries, resulting in a daily consumption of nearly 100 gallons per person, twice the European average! The JCP thus recommended that those countries raise their water fees to accurately reflect the cost of treating water being discharged into the Baltic system.

The challenges to the Baltic Sea are hardly over. To date, around 80 of the original 132 hot spots still remain heavily polluting. The main challenge, unsurprisingly, is to find the funding to deal with such spots. St. Petersburg, for example, continues as the Baltic's single largest polluter because it cannot raise the funds necessary to complete a partially built sewage treatment plant. The JCP nevertheless provides an interesting example of how to use both regulation and taxation to accomplish environmental goals. ◀

5.4 Distinctions Between Price and Quantity Approaches to Addressing Externalities

In this section, we compare price (taxation) and quantity (regulation) approaches to addressing externalities, using more complicated models in which the social efficiency implications of intervention might differ between the two approaches. The goal in comparing these approaches is to find the most efficient path to environmental targets. That is, for any reduction in pollution, the goal is to find the lowest-cost means of achieving that reduction.[12]

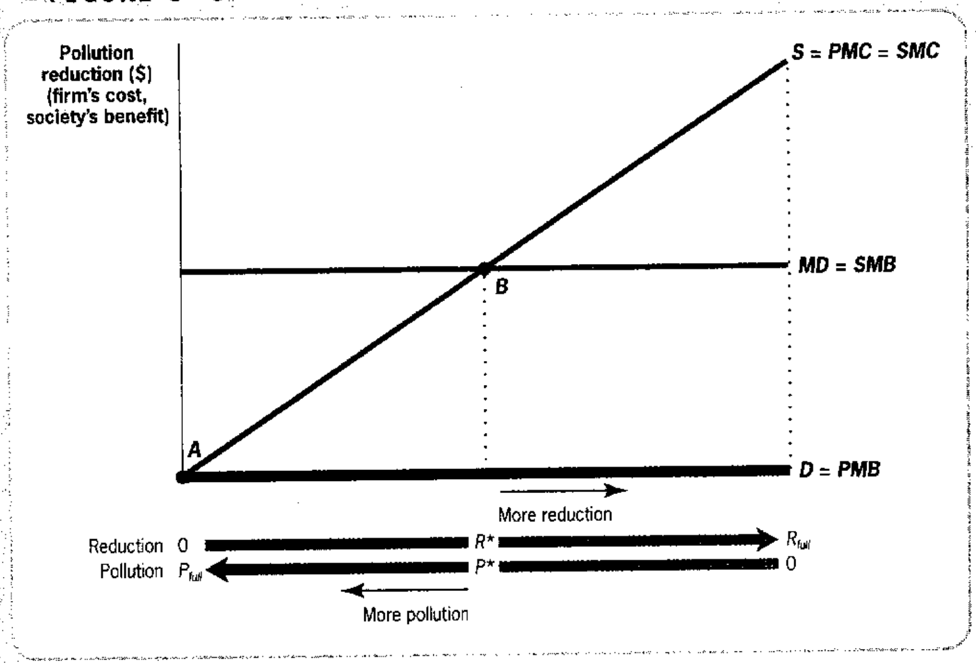
Basic Model

To illustrate the important differences between the price and quantity approaches, we have to add one additional complication to the basic competitive market that we have worked with thus far. In that model, the only way to reduce pollution was to cut back on production. In reality, there are many other technologies available for reducing pollution besides simply scaling back production. For example, to reduce sulfur dioxide emissions from coal-fired power plants, utilities can install smokestack scrubbers that remove SO_2 from the emissions and sequester it, often in the form of liquid or solid sludge that can be disposed of safely. Passenger cars can also be made less polluting by installing "catalytic converters," which turn dangerous nitrogen oxide into compounds that are not harmful to public health.

To understand the differences between price and quantity approaches to pollution reduction, it is useful to shift our focus from the market for a good (e.g., steel) to the "market" for pollution reduction, as illustrated in Figure 5-8. In this diagram, the horizontal axis measures the extent of pollution reduction undertaken by a plant; a value of zero indicates that the plant is not engaging in any pollution reduction. Thus, the horizontal axis also measures the amount of pollution: as you move to the right, there is more pollution reduction and less pollution. We show this by denoting *more reduction* as you move to the right on the horizontal axis; R_{full} indicates that pollution has been reduced to

12 The discussion of this section focuses entirely on the efficiency consequences of tax versus regulatory approaches to addressing externalities. There may be important equity considerations as well, however, which affect the government's decision about policy instruments. We will discuss the equity properties of taxation in Chapter 19.

▪ **FIGURE 5-8**



The Market for Pollution Reduction • The marginal cost of pollution reduction (*PMC* = *SMC*) is a rising function, while the marginal benefit of pollution reduction (*SMB*) is (by assumption) a flat marginal damage curve. Moving from left to right, the amount of pollution reduction increases, while the amount of pollution falls. The optimal level of pollution reduction is R^*, the point at which these curves intersect. Since pollution is the complement of reduction, the optimal amount of pollution is P^*.

zero. *More pollution* is indicated as you move to the left on the horizontal axis; at P_{full}, the maximum amount of pollution is being produced. The vertical axis represents the cost of pollution reduction to the plant, or the benefit of pollution reduction to society (that is, the benefit to other producers and consumers who are not compensated for the negative externality).

The *MD* curve represents the marginal damage that is averted by additional pollution reduction. This measures the social marginal benefit of pollution reduction. Marginal damage is drawn flat at $100 for simplicity, but it could be downward sloping due to diminishing returns. The private marginal benefit of pollution reduction is zero, so it is represented by the horizontal axis; there is no gain to the plant's private interests from reducing dumping.

The *PMC* curve represents the plant's private marginal cost of reducing pollution. The *PMC* curve slopes upward because of diminishing marginal productivity of this input. The first units of pollution are cheap to reduce: just tighten a few screws or put a cheap filter on the sludge pipe. Additional units of reduction become more expensive, until it is incredibly expensive to have a completely pollution-free production process. Because there are no externalities from the production of pollution reduction (the externalities come from the end product, reduced pollution, as reflected in the *SMB* curve, not from the process involved in actually reducing the pollution), the *PMC* is also the *SMC* of pollution reduction.

The free market outcome in any market would be zero pollution reduction. Since the cost of pollution is not borne by the plant, it has no incentive to reduce pollution. The plant will choose zero reduction and a full amount of pollution P_{full} (point *A*, at which the *PMC* of zero equals the *PMB* of zero).

What is the optimal level of pollution reduction? The optimum is *always* found at the point at which social marginal benefits and costs are equal, here point *B*. The optimal quantity of pollution reduction is $R^\star$: at that quantity, the marginal benefits of reduction (the damage done by pollution) and the marginal costs of reduction are equal. Note that setting the optimal amount of pollution reduction is the same as setting the optimal amount of pollution. If the free market outcome is pollution reduction of zero and pollution of P_{full}, then the optimum is pollution reduction of $R^\star$ and pollution of $P^\star$.

Price Regulation (Taxes) vs. Quantity Regulation in This Model

Now, contrast the operation of taxation and regulation in this framework. The optimal tax, as before, is equal to the marginal damage done by pollution, \$100. In this situation, the government would set a tax of \$100 on each unit of pollution. Consider the plant's decision under this tax. For each unit of pollution the plant makes, it pays a tax of \$100. If there is any pollution reduction that the plant can do that costs less than \$100, it will be cost-effective to make that reduction: the plant will pay some amount less than \$100 to get rid of the pollution, and avoid paying a tax of \$100. With this plan in place, plants will have an incentive to reduce pollution up to the point at which the cost of that reduction is equal to the tax of \$100. That is, plants will "walk up" their marginal cost curves, reducing pollution up to a reduction of $R^\star$ at point *B*. Beyond that point, the cost of reducing pollution exceeds the \$100 that they pay in tax, so they will just choose to pay taxes on any additional units of pollution rather than to reduce pollution further. Thus, a Pigouvian (corrective) tax equal to \$100 achieves the socially optimal level of pollution reduction, just as in the earlier analysis.

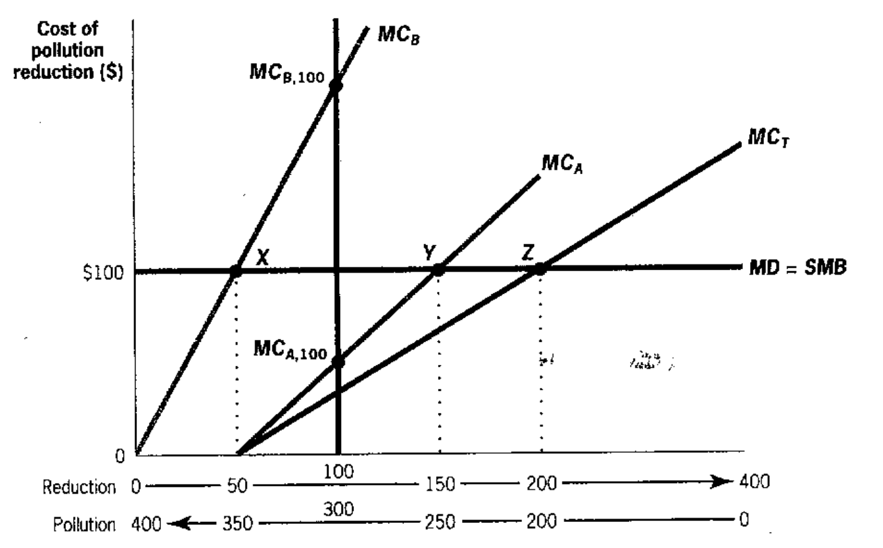
Regulation is even more straightforward to analyze in this framework. The government simply mandates that the plant reduce pollution by an amount $R^\star$, to get to the optimal pollution level $P^\star$. Regulation seems more difficult than taxation because, in this case, the government needs to know not only *MD* but also the shape of the *MC* curve as well. This difficulty is, however, just a feature of our assumption of constant *MD*; for the more general case of a falling *MD*, the government needs to know the shapes of both *MC* and *MD* curves in order to set either the optimal tax or the optimal regulation.

Multiple Plants with Different Reduction Costs

Now, let's add two wrinkles to the basic model. First, suppose there are now two steel plants doing the dumping, with each plant dumping 200 units of sludge into the river each day. The marginal damage done by each unit of sludge is \$100, as before. Second, suppose that technology is now available to reduce sludge associated with production, but this technology has different costs at the two different plants. For plant A reducing sludge is cheaper at any level of reduction, since it has a newer production process. For the second plant, B, reducing sludge is much more expensive for any level of reduction.

Figure 5-9 summarizes the market for pollution reduction in this case. In this figure, there are separate marginal cost curves for plant A (MC_A) and for plant B (MC_B). At every level of reduction, the marginal cost to plant A is lower than the marginal cost to plant B, since plant A has a newer and more efficient production process available. The total marginal cost of reduction in the market, the horizontal sum of these two curves, is MC_T: for any total reduction in pollution, this curve indicates the cost of that reduction if it is distributed most efficiently across the two plants. For example, the total marginal cost of a reduction of 50 units is \$0, since plant A can reduce 50 units for free; so the efficient combination is to have plant A do all the reducing. The socially efficient level of pollution reduction (and of pollution) is the intersection of this MC_T curve with the marginal damage curve, MD, at point Z, indicating a reduction of 200 units (and pollution of 200 units).

▪ **FIGURE 5-9**



Pollution Reduction with Multiple Firms • Plant A has a lower marginal cost of pollution reduction at each level of reduction than does plant B. The optimal level of reduction for the market is the point at which the sum of marginal costs equals marginal damage (at point Z, with a reduction of 200 units). An equal reduction of 100 units for each plant is inefficient since the marginal cost to plant B (MC_B) is so much higher than the marginal cost to plant A (MC_A). The optimal division of this reduction is where each plant's marginal cost is equal to the social marginal benefit (which is equal to marginal damage). This occurs when plant A reduces by 150 units and plant B reduces by 50 units, at a marginal cost to each of \$100.

Policy Option 1: Quantity Regulation Let's now examine the government's policy options within the context of this example. The first option is regulation: the government can demand a total reduction of 200 units of sludge from the market. The question then becomes: How does the government decide how much reduction to demand from each plant? The typical regulatory solution to this problem in the past was to ask the plants to split the burden: each plant reduces pollution by 100 units to get to the desired total reduction of 200 units.

This is not an efficient solution, however, because it ignores the fact that the plants have different marginal costs of pollution reduction. At an equal level of pollution reduction (and pollution), each unit of reduction costs less for plant *A* (MC_A) than for plant *B* (MC_B). If, instead, we got more reduction from plant *A* than from plant *B*, we could lower the total social costs of pollution reduction by taking advantage of reduction at the low-cost option (plant *A*). So society as a whole is worse off if plant *A* and plant *B* have to make equal reduction than if they share the reduction burden more efficiently.

This point is illustrated in Figure 5-9. The efficient solution is one where, for each plant, the marginal cost of reducing pollution is set equal to the social marginal benefit of that reduction; that is, where each plant's marginal cost curve intersects with the marginal benefit curve. This occurs at a reduction of 50 units for plant *B* (point *X*), and 150 units for plant *A* (point *Y*). Thus, mandating a reduction of 100 units from each plant is inefficient; total costs of achieving a reduction of 200 units will be lower if plant *A* reduces by a larger amount.

Policy Option 2: Price Regulation Through a Corrective Tax The second approach is to use a Pigouvian corrective tax, set equal to the marginal damage, so each plant would face a tax of $100 on each unit of sludge dumped. Faced with this tax, what will each plant do? For plant *A*, any unit of sludge reduction up to 150 units costs less than $100, so plant *A* will reduce its pollution by 150 units. For plant *B*, any unit of sludge reduction up to 50 units costs less than $100, so it will reduce pollution by 50 units. Note that these are exactly the efficient levels of reduction! Just as in our earlier analysis, Pigouvian taxes cause efficient production by raising the cost of the input by the size of its external damage, thereby raising private marginal costs to social marginal costs. Taxes are preferred to quantity regulation, with an equal distribution of reductions across the plants, because taxes give plants more flexibility in choosing their optimal amount of reduction, allowing them to choose the efficient level.

Policy Option 3: Quantity Regulation with Tradable Permits Does this mean that taxes *always* dominate quantity regulation with multiple plants? Not necessarily. If the government had mandated the appropriate reduction from each plant (150 units from *A* and 50 units from *B*), then quantity regulation would have achieved the same outcome as the tax. Such a solution would, however, require much more information. Instead of just knowing the marginal damage and the total marginal cost, the government would also have to know the marginal cost curves of each individual plant. Such detailed information would be hard to obtain.

Quantity regulation can be rescued, however, by adding a key flexibility: issue permits that allow a certain amount of pollution and let the plants trade. Suppose the government announces the following system: it will issue 200 permits that entitle the bearer to produce one unit of pollution. It will initially provide 100 permits to each plant. Thus, in the absence of trading, each plant would be allowed to produce only 100 units of sludge, which would in turn require each plant to reduce its pollution by half (the inefficient solution previously described).

If the government allows the plants to trade these permits to each other, however, plant *B* would have an interest in buying permits from plant *A*. For plant *B*, reducing sludge by 100 units costs $MC_{B,100}$, a marginal cost much greater than plant *A*'s marginal cost of reducing pollution by 100 units, which is $MC_{A,100}$. Thus, plants *A* and *B* can be made better off if plant *B* buys a permit from plant *A* for some amount between $MC_{A,100}$ and $MC_{B,100}$, so that plant *B* would pollute 101 units (reducing only 99 units) and plant *A* would pollute 99 units (reducing 101 units). This transaction is beneficial for plant *B* because as long as the cost of a permit is below $MC_{B,100}$, plant *B* pays less than the amount it would cost plant *B* to reduce the pollution on its own. The trade is beneficial for plant *A* as long as it receives for a permit at least $MC_{A,100}$, since it can reduce the sludge for a cost of only $MC_{A,100}$, and make money on the difference.

By the same logic, a trade would be beneficial for a second permit, so that plant *B* could reduce sludge by only 98, and plant *A* would reduce by 102. In fact, any trade will be beneficial until plant *B* is reducing by 50 units and plant *A* is reducing by 150 units. At that point, the marginal costs of reduction across the two producers are equal (to $100), so that there are no more gains from trading permits.

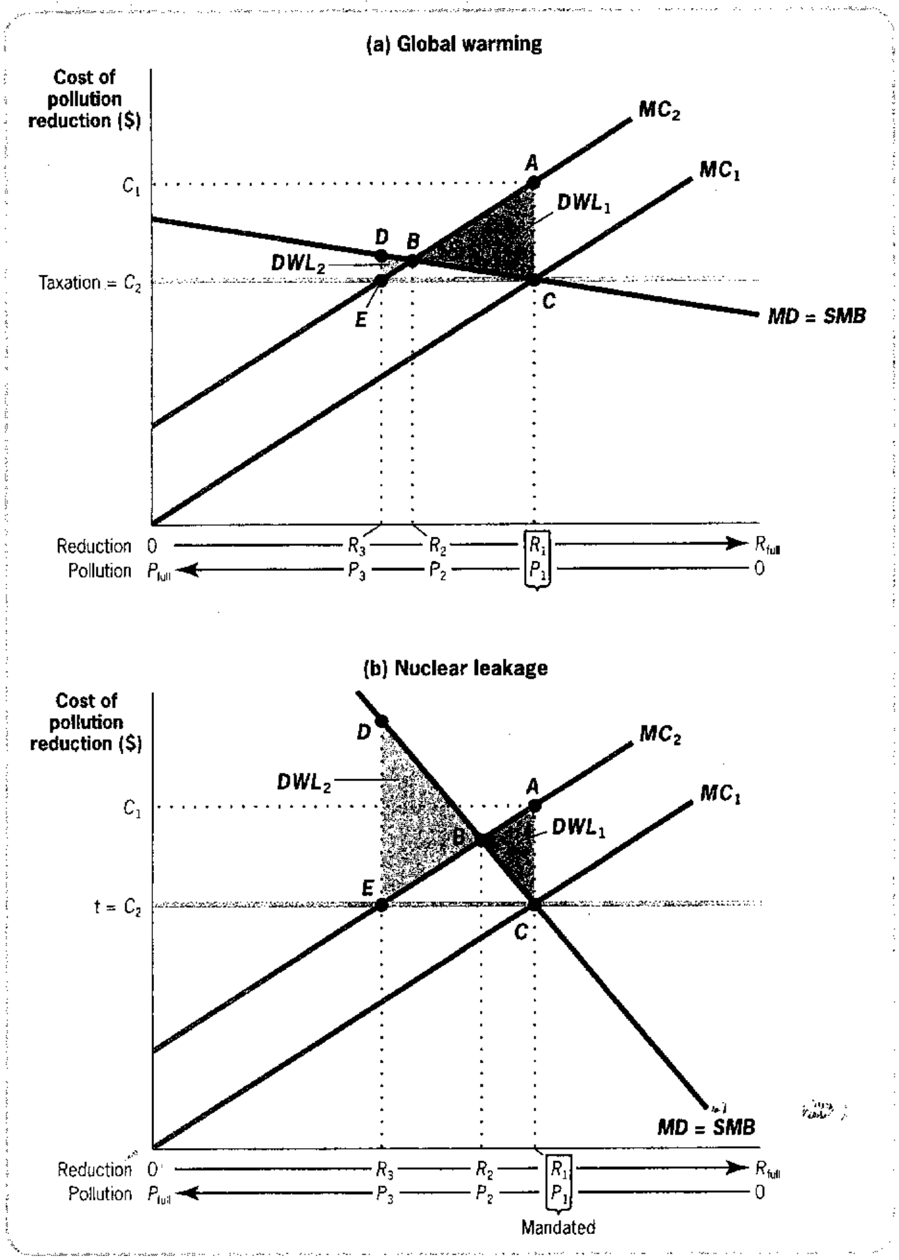
What is going on here? We have simply returned to the intuition of the Coasian solution: we have *internalized the externality by providing property rights to pollution.* So, like Pigouvian taxes, trading allows the market to incorporate differences in the cost of pollution reduction across firms. In Chapter 6, we discuss a successful application of trading to the problem of environmental externalities.

Uncertainty About Costs of Reduction

Differences in reduction costs across firms are not the only reason that taxes or regulation might be preferred. Another reason is that the costs or benefits of regulation could be uncertain. Consider two extreme examples of externalities: global warming and nuclear leakage. Figure 5-10 extends the pollution reduction framework from Figure 5-8 to the situation in which the marginal damage (which is equal to the marginal social benefit of pollution reduction) is now no longer constant, but falling. That is, the benefit of the first unit of pollution reduction is quite high, but once the production process is relatively pollution-free, additional reductions are less important (that is, there are diminishing marginal returns to reduction).

Panel (a) of Figure 5-10 considers the case of global warming. In this case, the exact amount of pollution reduction is not so critical for the environment.

▪ FIGURE 5-10



Market for Pollution Reduction with Uncertain Costs • In the case of global warming (panel (a)), the marginal damage is fairly constant over large ranges of emissions (and thus emission reductions). If costs are uncertain, then taxation at level $t = C_2$ leads to a much lower deadweight loss (*DBE*) than does regulation of R_1 (*ABC*). In the case of nuclear leakage (panel (b)), the marginal damage is very steep. If costs are uncertain, then taxation leads to a much larger deadweight loss (*DBE*) than does regulation (*ABC*).

Since what determines the extent of global warming is the total accumulated stock of carbon dioxide in the air, which accumulates over many years from sources all over the world, even fairly large shifts in carbon dioxide pollution in one country today will have little impact on global warming. In that case, we say that the social marginal benefit curve (which is equal to the marginal damage from global warming) is *very flat:* that is, there is little benefit to society from modest additional reductions in carbon dioxide emissions.

Panel (b) of Figure 5-10 considers the case of radiation leakage from a nuclear power plant. In this case, a very small difference in the amount of nuclear leakage can make a huge difference in terms of lives saved. Indeed, it is possible that the marginal damage curve (which is once again equal to the marginal social benefits of pollution reduction) for nuclear leakage is almost vertical, with each reduction in leakage being equally important in terms of saving lives. Thus, the social marginal benefit curve in this case is *very steep.*

Now, in both cases, imagine that we don't know the true costs of pollution reduction on the part of firms or individuals. The government's best guess is that the true marginal cost of pollution reduction is represented by curve MC_1 in both panels. There is a chance, however, that the marginal cost of pollution reduction could be much higher, as represented by the curve MC_2. This uncertainty could arise because the government has an imperfect understanding of the costs of pollution reduction to the firm, or it could arise because both the government and the firms are uncertain about the ultimate costs of pollution reduction.

Implications for Effect of Price and Quantity Interventions This uncertainty over costs has important implications for the type of intervention that reduces pollution most efficiently in each of these cases. Consider regulation first. Suppose that the government mandates a reduction, R_1, which is the optimum if costs turn out to be given by MC_1: this is where social marginal benefits equal social marginal costs of reduction if marginal cost equals MC_1. Suppose now that the marginal costs actually turn out to be MC_2, so that the optimal reduction should instead be R_2, where $SMB = MC_2$. That is, regulation is mandating a reduction in pollution that is too large, with the marginal benefits of the reduction being below the marginal costs. What are the efficiency implications of this mistake?

In the case of global warming (panel (a)), these efficiency costs are quite high. With a mandated reduction of R_1, firms will face a cost of reduction of C_1, the cost of reducing by amount R_1 if marginal costs are described by MC_2. The social marginal benefit of reduction of R_1 is equal to C_2, the point where R_1 intersects the *SMB* curve. Since the cost to firms (C_1) is so much higher than the benefit of reduction (C_2), there is a large deadweight loss (DWL_1) of area *ABC* (the triangle that incorporates all units where cost of reduction exceeds benefits of reduction).

In the case of nuclear leakage (panel (b)), the costs of regulation are very low. Once again, with a mandated reduction of R_1, firms will face a cost of reduction of C_1, the cost of reducing by amount R_1 if marginal costs are described by MC_2. The social marginal benefit of reduction at R_1 is once again equal to C_2. In this case, however, the associated deadweight loss triangle *ABC* (DWL_1) is much smaller than in panel (a), so the inefficiency from regulation is much lower.

Now, contrast the use of corrective taxation in these two markets. Suppose that the government levies a tax designed to achieve the optimal level of reduction if marginal costs are described in both cases by MC_1, which is R_1. As discussed earlier, the way to do this is to choose a tax level, t, such that the firm chooses a reduction of R_1. In both panels, the tax level that will cause firms to choose reduction R_1 is a tax equal to C_2, where MC_1 intersects MD. A tax of this amount would cause firms to do exactly R_1 worth of reduction, if marginal costs are truly determined by MC_1.

If the true marginal cost ends up being MC_2, however, the tax causes firms to choose a reduction of R_3, where their true marginal cost is equal to the tax (where $t = MC_2$ at point E), so that there is *too little* reduction. In the case of global warming in panel (a), the deadweight loss (DWL_2) from reducing by R_3 instead of R_2 is only the small area DBE, representing the units where social marginal benefits exceed social marginal costs. In the case of nuclear leakage in panel (b), however, the deadweight loss (DWL_2) from reducing by R_3 instead of R_2 is a much larger area, DBE, once again representing the units where social marginal benefits exceed social marginal costs.

Implications for Instrument Choice The central intuition here is that *the instrument choice depends on whether the government wants to get the amount of pollution reduction right or whether it wants to minimize costs.* Quantity regulation assures there is as much reduction as desired, regardless of the cost. So, if it is critical to get the amount exactly right, quantity regulation is the best way to go. This is why the efficiency cost of quantity regulation under uncertainty is so much lower with the nuclear leakage case in panel (b). In this case, it is critical to get the reduction close to optimal; if we end up costing firms extra money in the process, so be it. For global warming, getting the reduction exactly right isn't very important; so it is inefficient in this case to mandate a very costly option for firms.

Price regulation through taxes, on the other hand, assures that the cost of reductions never exceeds the level of the tax, but leaves the amount of reduction uncertain. That is, firms will never reduce pollution beyond the point at which reductions cost more than the tax they must pay (the point at which the tax intersects their true marginal cost curve, MC_2). If marginal costs turn out to be higher than anticipated, then firms will just do less pollution reduction. This is why the deadweight loss of price regulation in the case of global warming is so small in panel (a): the more efficient outcome is to get the exact reduction wrong but protect firms against very high costs of reduction. This is clearly not true in panel (b): for nuclear leakage, it is most important to get the quantity close to right (almost) regardless of the cost to firms.

In summary, quantity regulations ensure environmental protection, but at a variable cost to firms, while price regulations ensure the cost to the firms, but at a variable level of environmental protection. So, if the value of getting the environmental protection close to right is high, then quantity regulations will be preferred; but if getting the protection close to right is not so important, then price regulations are a preferred option.

5.5
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5.5 Conclusion

Externalities are the classic answer to the "when" question of public finance: when one party's actions affect another party, and the first party doesn't fully compensate (or get compensated by) the other for this effect, then the market has failed and government intervention is potentially justified. In some cases, the market is likely to find a Coasian solution whereby negotiations between the affected parties lead to the "internalization" of the externality. For many cases, however, only government intervention can solve the market failure.

This point naturally leads to the "how" question of public finance. There are two classes of tools in the government's arsenal for dealing with externalities: price-based measures (taxes and subsidies) and quantity-based measures (regulation). Which of these methods will lead to the most efficient regulatory outcome depends on factors such as the heterogeneity of the firms being regulated, the flexibility embedded in quantity regulation, and the uncertainty over the costs of externality reduction. In the next chapter, we take these somewhat abstract principles and apply them to some of the most important externalities facing the United States (and the world) today.

▶ HIGHLIGHTS

- Externalities arise whenever the actions of one party make another party worse or better off, yet the first party neither bears the costs nor receives the benefits of doing so.
- Negative externalities cause overproduction of the good in a competitive market, while positive externalities cause underproduction of the good in a competitive market, in both cases leading to a deadweight loss.
- Private markets may be able to "internalize" the problems of externalities through negotiation, but this Coasian process faces many barriers that make it an unlikely solution to global externalities, such as most environmental externalities.
- The government can use either price (tax or subsidy) or quantity (regulation) approaches to addressing externalities.
- When firms have different marginal costs of pollution reduction, price mechanisms are a more efficient means of accomplishing environmental goals unless quantity regulation is accompanied by the ability to meet regulatory targets by trading pollution permits across polluters.
- If there is uncertainty about the marginal costs of pollution reduction, then the relative merits of price and quantity regulations will depend on the steepness of the marginal benefit curve. Quantity regulation gets the amount of pollution reduction right, regardless of cost, and so is more appropriate when marginal benefits are steep; price regulation through taxation gets the costs of pollution reduction right, regardless of quantity, so it is more appropriate when marginal benefits are flat.

▶ QUESTIONS AND PROBLEMS

1. Peterson, Hoffer, and Millner (1995) showed that air bag use has led to increases in car crashes. Despite this finding, the government mandates that new cars have air bags, rather than taxing their use. Is this policy a contradiction?

2. When the state of Virginia imposed stricter regulations on air pollution in 2003, it also authorized an auction of pollution permits, allowing some plants to emit larger amounts of ozone-depleting chemicals than would otherwise be allowed, and some to emit less. Theory predicts that this auction led to a socially efficient allocation of pollution. Describe how this outcome would occur.

3. Can an activity generate both positive and negative externalities at the same time? Explain your answer.

4. In the midwestern United States, where winds tend to blow from west to east, states tend to more easily approve new polluting industries near their eastern borders than in other parts of the state. Why do you think this is true?

5. Can government assignment and enforcement of property rights internalize an externality? Will this approach work as well as, better than, or worse than direct government intervention? Explain your answers and describe one of the difficulties associated with this solution.

6. In close congressional votes, many members of Congress choose to remain "undecided" until the last moment. Why might they do this? What lesson does this example teach about a potential shortcoming of the Coasian solution to the externality problem?

7. Suppose that a firm's marginal production costs are given by $MC = 10 + 3Q$. The firm's production process generates a toxic waste, which imposes an increasingly large cost on the residents of the town where it operates: the marginal external cost associated with the Qth unit of production is given by $6Q$. What is the marginal private cost associated with the 10th unit produced? What is the total marginal cost to society associated with producing the 10th unit (the marginal social cost of the 10th unit)?

8. In two-car automobile accidents, passengers in the larger vehicle are significantly more likely to survive than are passengers in the smaller vehicle. In fact, death probabilities are decreasing in the size of the vehicle you are driving, and death probabilities are increasing in the size of the vehicle you collide with. Some politicians and lobbyists have argued that this provides a rationale for encouraging the sale of larger vehicles and discouraging legislation that would induce automobile manufacturers to make smaller cars. Critically examine this argument using the concept of externalities.

9. Why do governments sometimes impose quantity regulations that limit the level of negative-externality-inducing consumption? Why do governments sometimes impose price regulations by taxing this consumption?

10. Answer the following two questions for each of the following examples: (i) smoking by individuals; (ii) toxic waste production by firms; (iii) research and development by a high-tech firm; and (iv) individual vaccination against communicable illness.
    a. Is there an externality? If so, describe it, including references to whether it is positive or negative, and whether it is a consumption or production externality.
    b. If there is an externality, does it seem likely that private markets will arise that allow this externality to be internalized? Why or why not?

▶ ADVANCED QUESTIONS

11. Warrenia has two regions. In Oliviland, the marginal benefit associated with pollution cleanup is $MB = 300 - 10Q$, while in Linneland, the marginal benefit associated with pollution cleanup is $MB = 200 - 4Q$. Suppose that the marginal cost of cleanup is constant at \$12 per unit. What is the optimal level of pollution cleanup in each of the two regions?

12. The private marginal benefit associated with a product's consumption is $PMB = 360 - 4Q$ and the private marginal cost associated with its production is $PMC = 6P$. Furthermore, the marginal external damage associated with this good's production is $MD = 2P$. To correct the externality, the government decides to impose a tax of T per unit sold. What tax T should it set to achieve the social optimum?

13. Suppose that demand for a product is $Q = 1200 - 4P$ and supply is $Q = -200 + 2P$. Furthermore, suppose that the marginal external damage of this product is \$8 per unit. How many more units of this product will the free market produce than is socially optimal? Calculate the deadweight loss associated with the externality.

14. The marginal damage averted from pollution cleanup is $MD = 200 - 5Q$. The marginal cost associated with pollution cleanup is $MC = 10 + Q$.

a. What is the optimal level of pollution reduction?

b. Show that this level of pollution reduction could be accomplished through taxation. What tax per unit would generate the optimal amount of pollution reduction?

15. Two firms are ordered by the federal government to reduce their pollution levels. Firm *A*'s marginal costs associated with pollution reduction is $MC = 20 + 4Q$. Firm *B*'s marginal costs associated with pollution reduction is $MC = 10 + 8Q$. The marginal benefit of pollution reduction is $MB = 400 - 4Q$.

a. What is the socially optimal level of each firm's pollution reduction?

b. Compare the social efficiency of three possible outcomes: (1) require all firms to reduce pollution by the same amount; (2) charge a common tax per unit of pollution; or (3) require all firms to reduce pollution by the same amount, but allow pollution permits to be bought and sold.

16. One hundred commuters need to use a strip of highway to get to work. They all drive alone and prefer to drive in big cars—it gives them more prestige and makes them feel safer. Bigger cars cost more per mile to operate, however, since their gas mileage is lower. Worse yet, bigger cars cause greater permanent damage to roads.

The weight of the car is w. Suppose that the benefits from driving are $4w$, while the costs are $3/2 \times w^2$. The damage to roads is $1/3 \times w^3$. Assume that individuals have utility functions of the form $U = x$, where x are the net benefits from driving a car of a given size.

a. What car weight will be chosen by drivers?

b. What is the optimal car weight? If this differs from (a), why does it?

c. Can you design a toll system that causes drivers to choose the optimal car weight? If so, then how would such a system work?

17. Firms *A* and *B* each produce 80 units of pollution. The federal government wants to reduce pollution levels. The marginal costs associated with pollution reduction are $MC^A = 50 + 3Q^A$ for firm *A* and $MC^B = 20 + 6Q^B$ for firm *B*, where Q^A and Q^B are the quantities of pollution *reduced* by each firm. Society's marginal benefit from pollution reduction is given by $MB = 590 - 3Q^{tot}$, where Q^{tot} is the total reduction in pollution.

a. What is the socially optimal level of each firm's pollution reduction?

b. How much total pollution is there in the social optimum?

c. Explain why it is inefficient to give each firm an *equal* number of pollution permits (if they are not allowed to trade them).

d. Explain how the social optimum can be achieved if firms are given equal numbers of pollution permits but *are* allowed to trade them.

e. Can the social optimum be achieved using a tax on pollution?

6 Externalities in Action: Environmental and Health Externalities

For many years, Caldwell Pond in Alstead, New Hampshire, had been one of the state's best trout ponds, yielding brook trout that weighed upward of two pounds. By 1980, something had changed. That spring, the New Hampshire Fish and Game Department stocked the 28-acre pond with young fish, known as fingerling trout. Shortly afterward, visitors to the pond began seeing dead fish all over the pond's bottom.

What happened? Tests of the pond water uncovered the culprit: a rapid rise in the acidity of the water. Acidity is measured on a pH scale, where 7.0 is neutral and 3.0 is the acidity of vinegar. In 1948, the lake had a pH of 5.8 to 6.2; the 1980 samples of pond water had a pH of 4.2 to 4.7. The lake was over 30 times more acidic than it had been 30 years earlier.[1] The cause of this increased acidity was the phenomenon known as *acid rain.*

The primary causes of acid rain are clear. When sulfur dioxide (SO_2) and nitrogen oxides (NO_X) are released into the atmosphere, they combine with hydrogen to form sulfuric and nitric acids respectively. These acids (in liquid or solid form, also known as *particulates*) may fall back to the earth hundreds of miles away from their original source, in a process called *acid deposition,* more popularly known as **acid rain.** The majority of acid rain in North America is created by SO_2 emissions, two-thirds of which come from coal-fired power plants, which are heavily concentrated in the Ohio River Valley.[2]

acid rain Rain that is unusually acidic due to contamination by emissions of sulfur dioxide (SO_2) and nitrogen oxide (NO_x).

Acid rain is a classic negative production externality. As a by-product of their production, power plants in the Midwest damage the quality of life along the east coast of the United States. Private-sector (Coasian) solutions are unavailable because of the problems noted in the previous chapter, such as negotiation difficulties with hundreds of polluters and millions of affected individuals. Thus, government intervention is required to address this externality. In fact, the government has intervened to reduce acid rain for over 30 years. The story of this intervention and the effects it has had on the environ-

[1] Bryant (1980).

[2] Ellerman et al. (2000), p. 5.

ment, on health, and on the economy provides an excellent example of the possibilities and limitations of government policy toward the environment.

In this chapter, we put the theoretical tools developed in Chapter 5 to use in examining several examples of environmental and health externalities. In particular, the United States' experience with acid rain regulation highlights the enormous value of a tool introduced in the previous chapter: emissions trading. Allowing trading within the acid rain regulatory scheme lowered the costs of these regulations by half or more. This lesson has proved influential in the debate over global warming, likely the largest environmental issue that the world will face in the coming century. In this chapter, we discuss initial efforts to address global warming and the important role that trading can play in future regulatory interventions.

We then turn to another major potential source of externalities, health externalities, and in particular those caused by cigarette smoking. Health behaviors provide an excellent forum for assessing when actions cause, and do not cause, externalities on others, as well as for raising the question of whether actions an individual takes that harm only that individual should be regulated by the government.

6.1 Acid Rain

In Alstead, New Hampshire, acid rain raised the acidity of a popular fishing pond and killed the trout that lived in it. Indeed, acid rain is the primary cause of acidity in lakes and streams in the United States, and it causes a cascade of effects that harm or kill individual fish, reduce fish populations, completely eliminate fish species, and decrease biodiversity. By 1989, over 650 U.S. lakes, which once supported a variety of fish species, were now too acidic to support anything but acid-tolerant largemouth bass.[3]

The Damage of Acid Rain

Raising the acidity of lakes and other bodies of water is just one way in which acid rain affects the environment. Acid rain causes damage in a variety of other ways as well:[4]

- *Forest erosion:* Acid rain causes slower growth, and injury and death in a variety of trees, and it has been implicated in forest and soil degradation in many areas of the eastern United States, particularly in the high-elevation forests of the Appalachian Mountains from Maine to Georgia.[5]

[3] Interestingly, fishing may seem temporarily good in these acid-damaged lakes because the fish are starving (and therefore bite more!) as their food supply dies off.

[4] Acid rain information comes from the EPA's Web site at http://www.epa.gov.

[5] Acid rain does not usually kill trees directly. It is more likely to weaken trees by damaging their leaves, limiting the nutrients available to them, exposing them to toxic substances slowly released from the soil, and weakening their resistance against insects.

- *Damage to property:* Evaporation of acidic droplets from car surfaces causes irreparable damage to certain cars' paint jobs, forcing repainting to repair the problem, or requiring the use of acid-resistant paints. Acid rain also contributes to the corrosion of metals (such as bronze) and the deterioration of paint and stone (such as marble and limestone). In 1985, the government estimated the cost of acid rain–related damage to property at $5 billion per year.
- *Reduced visibility:* Sulfates and nitrates that form in the atmosphere make it hard for us to see as far or as clearly through the air. Sulfate particles account for 50 to 70% of the visibility reduction in the eastern part of the United States, a reduction that affects people's enjoyment of national parks such as the Shenandoah and the Great Smoky Mountains National Parks. Reductions in acid rain through the government programs described later in this chapter are expected to improve the visual range in the eastern United States by 30% in the long run.
- *Adverse health outcomes:* The harm to people from acid rain is not direct. Walking in acid rain, or even swimming in an acid lake, is no more dangerous than walking or swimming in clean water. However, the sulfur dioxide and nitrogen oxides that cause acid rain interact with the atmosphere to form fine particulates that can be inhaled deep into people's lungs. Fine particulates can also penetrate indoors. Many scientific studies have identified a relationship between elevated levels of fine particulates and increased illness and premature death from heart and lung disorders such as asthma and bronchitis. When fully implemented by the year 2010, the public health benefits of the Acid Rain Program are estimated to be valued at $50 billion annually, due to decreased mortality, hospital admissions, and emergency room visits.

History of Acid Rain Regulation

1970 Clean Air Act Landmark federal legislation that first regulated acid rain–causing emissions by setting maximum standards for atmospheric concentrations of various substances, including SO_2.

Regulation of the emissions that cause acid rain began with the **1970 Clean Air Act,** which set maximum standards for atmospheric concentrations of various substances, including SO_2. The act set New Source Performance Standards (NSPS) for any *new* coal-fired power plant, forcing any new plant to reduce emissions in one of two ways: either by switching to coal with a lower sulfur content, or by installing scrubbers, which are devices that remove a large portion of pollutants from the plant's exhaust fumes. In terms of the theory of government policy discussed in the previous chapter, the government chose a regulatory (quantity) approach over a tax (price) approach for dealing with this environmental problem.

Total emissions of SO_2 declined by the early 1980s, but some new concerns arose that motivated additional attention to the emissions issue. Most importantly, the vast majority of emissions came from older plants that were not subject to the NSPS. By mandating NSPS only for new plants, the 1970 act gave utilities great incentive to run older, dirtier plants for longer than policy makers had predicted (i.e., longer than the plants' natural "lifetimes"). Moreover, an additional requirement put in place in 1977 that all new plants have scrubbers increased the expense of building new plants and thus further encouraged the upkeep of older plants. These problems are excellent examples of the hazards of *partial policy reform*. By mandating regulations only for new plants, the government opened a major loophole in the law that encouraged firms to extend the use of outdated, more highly polluting older plants, thus undercutting the effectiveness of the law.

The 1990 Amendments and Emissions Trading In 1990, a series of amendments to the Clean Air Act were passed, most notably a regulation that mandated a reduction of more than 50% in the level of SO_2 emissions nationwide, and included all plants, even older ones. A key feature of the amendment was that it established an **SO_2 allowance system** that granted plants permits to emit SO_2 in limited quantities, based on their historical fuel utilization.[6] Plants were allowed to buy, sell, and save (for future years) these allowances. Plants that found it very costly to reduce emissions could try to purchase allowances from other plants that could more easily reduce emissions below their allowance level. The allowance market was supposed to increase the cost-effectiveness of the plan by encouraging utilities to exploit the differences in the cost of reducing emissions (something discussed theoretically in Chapter 5). Older plants, for which reductions were most expensive, could buy allowances from newer plants, for which reductions were cheaper. Heeding the advice of economists on the benefits of trading, the market for permits involved very few restrictions: trading could occur anywhere within the nation, no review or approval of trades was required, anyone (plants, brokerage firms, and so on) could trade, and the frequency and mechanism of trading were unlimited.

This amendment drew strong opposition from two different sources. On the one hand, the sizeable SO_2 restrictions were criticized on economic grounds by the utilities and coal miners, particularly those in eastern states whose coal supplies were high in sulfur content. An industry study in 1989 predicted the cost of fully implementing an acid rain program at $4.1 billion to $7.4 billion annually, with a loss of up to 4 million jobs.[7] On the other hand, the allowance and trading system was strongly criticized by environmentalists. Former Minnesota senator Eugene McCarthy likened the allowance system to the indulgences that church members could buy in the Middle Ages, which for a price forgave them their sins, calling this a "pollution absolution." McCarthy and other environmentalists opposed these amendments on the grounds that they were creating a "market for vice and virtue."[8]

SO_2 allowance system The feature of the 1990 amendments to the Clean Air Act that granted plants permits to emit SO_2 in limited quantities and allowed them to trade those permits.

[6] For example, let's say Brian runs a power plant that in 1987 burned 10 billion Btus' (British thermal units, a measure of energy) worth of coal and emitted 15 tons of SO_2 into the atmosphere. This works out to an emissions rate of 3 pounds of SO_2 per million Btus, which means Brian runs a very dirty plant. Starting in 2000, each year the EPA would grant Brian only enough emission allowances to let him pollute as if his emissions rate in 1987 had been a much lower 1.2 pounds of SO_2 per million Btus. In this case, he would be given only six allowances, one for each ton he is now allowed to emit. Brian would thus have to reduce his emissions drastically (by 60%, from 15 to 6) or buy allowances from another power plant.

[7] Perciasepe (1999).

[8] McCarthy (1990).

EMPIRICAL EVIDENCE

ESTIMATING THE ADVERSE HEALTH EFFECTS OF PARTICULATES

The estimates of the health costs of particulates come from a large empirical literature on pollution and health outcomes. The typical approach taken in this literature is to relate adult mortality in a geographical area to the level of particulates in the air in that area. The results from this type of analysis are suspect, however, due to the key empirical problem highlighted in Chapter 3: the areas with more particulates may differ from areas with fewer particulates in many other ways, not just in the amount of particulates in the air. Imagine, for example, that researchers compared two areas, one with old plants that emit a lot of particulates, and one with newer plants that are much cleaner. If the researchers found higher mortality in the areas with the older dirty plants, they might attribute this to the effects of particulates on human health. Suppose, however, that older plants are also less safe places to work than newer plants. In this case, the higher mortality in areas with older plants might be due to workplace accidents, not pollution. It is difficult to observe valid treatment and control groups in a situation like this; you can't just compare dirty areas to cleaner ones because so many other things could differ between them, imparting bias to the estimates.

Chay and Greenstone (2003) addressed this problem in a recent study, using the regulatory changes induced by the Clean Air Act of 1970. This act applied differentially to different counties in the United States, based on whether they were above or below a mandated "attainment" of clean air levels. Counties with emissions above a mandated threshold (nonattainment counties) were subject to state regulation, while those with similar emissions, but that fell just below that threshold, were not. In the nonattainment counties, this regulation led to a very large reduction in emissions (measured as total suspended particulates, TSPs) as shown in Figure 6-1. This figure shows TSPs over time for counties above and below the mandated threshold. For areas with TSPs below the mandated threshold, there was only a slight reduction in TSPs over time, from just above 60 to just below 60 micrograms per cubic meter. For areas above the mandated threshold (those areas that were subject to this regulation), there was a very large reduction in emissions after the legislation became effective in 1971, from over 100 to 80 micrograms per cubic meter.

Applying a term we learned in Chapter 3, we have an excellent *quasi-experiment* here. The treatment group is those areas that were in nonattainment, for which TSPs fell dramatically. The control group is those areas that were in attainment, for which there was little change in TSPs. These groups were similar beforehand, and should be subject to similar changes over time *other* than the regulatory intervention. Thus, the only change in nonattainment areas relative to attainment areas is the intervention itself, so that any effect on health represents a causal impact of regulation. Chay and Greenstone make this comparison by examining a clear indicator of bad health, the *infant mortality rate* (the share of newborns who die before their first birthday). Infants can develop severe and potentially fatal respiratory problems from particulates in the air.

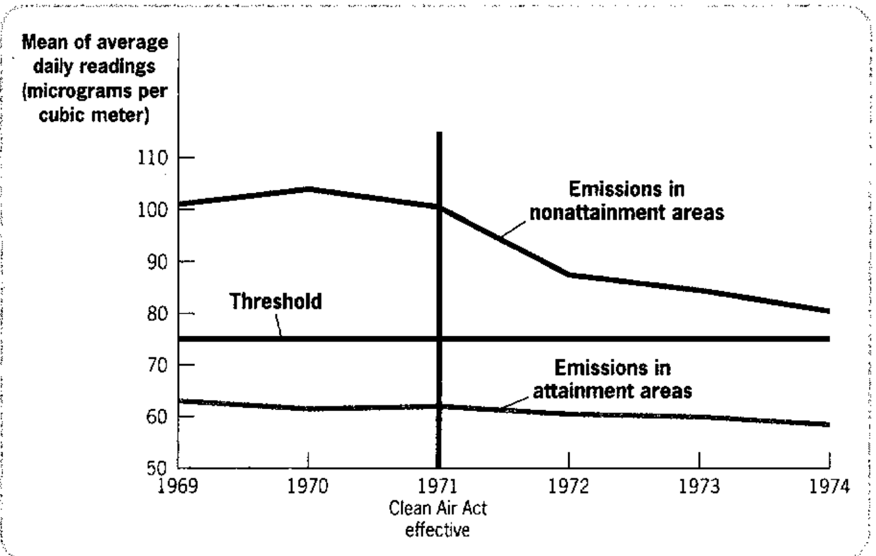
In fact, the costs of these regulations have been much lower than predicted due to the benefits of permit trading. Daniel Ellerman, an expert on acid rain regulations, estimates that the trading program lowered costs by more than half over the 1995–2007 period, from \$35 billion to \$15 billion.[9] A wider range of studies finds that the trading program has lowered estimated costs between 33% and 67%.[10]

The Clean Air Act amendments have shown that trading has worked, as economists suggested it would, to greatly improve the efficiency of regulation. Based on this success, trading regimes have gained in popularity in the environmental community in the United States and to a lesser extent around the world. Environmentalists have realized that more efficient regulation is in their

[9] Ellerman et al. (2000), Table 10.5.
[10] Ellerman et al. (2000), p. 296.

Chay and Greenstone's findings are striking: infant mortality declined substantially in areas with regulation-induced reductions in emissions, relative to areas where emissions were not mandated to fall. They found that each 10% decline in particulates leads to a 5% decline in the infant mortality rate. This estimate implies that 1,300 fewer infants died in 1972 as a result of the Clean Air Act of 1970, confirming in a much more convincing manner the high health costs of emissions and the benefits of regulation.

▪ **FIGURE 6-1**



Trends in Emissions in Counties That Were and Were Not Subject to the Clean Air Act • In the set of counties that had low levels of total suspended particulates (TSPs) before the CAA (attainment areas), there was little change in emissions over this time period. In the set of higher-emitting counties that were subject to the restrictions of the regulations (nonattainment areas), TSPs fell dramatically after 1971.

Source: Chay and Greenstone (2005), Figure 2a.

interest as well, as it reduces the economic opposition to increased government regulation. According to Ellerman (2000, p. 4), "Most observers quickly judged the program to be a great success. . . . In less than a decade, emissions trading has gone from being a pariah among policy makers to being a star—everybody's favorite way to deal with pollution problems."

Has the Clean Air Act Been a Success?

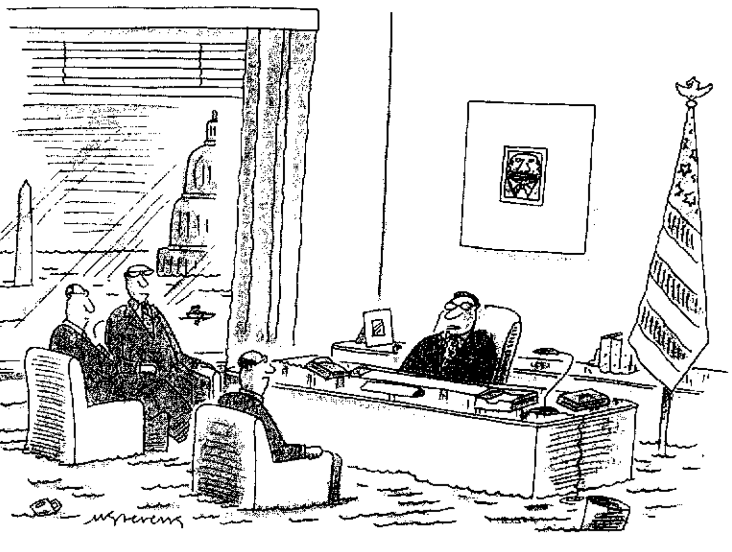
Economists are best at laying out the costs and benefits of alternative interventions and leaving it to others to decide if those interventions can be called successful or not. Clearly, the Clean Air Act, particularly after the 1990 amendments, has a lot to recommend it. However, it is much harder to determine whether the net economic costs from this program are smaller than its benefits. The set of regulations imposed by this program were clearly costly: Greenstone (2002) estimates that in its first 15 years, the Clean Air Act cost almost 600,000 jobs and $75 billion in output in pollution-intensive industries. At the same time, these regulations were clearly beneficial in terms of lowering the costs of particulate emissions, particularly in terms of health improvements. The trick is to put all of these observations together into a definite conclusion. (We will discuss how economists approach this problem in Chapter 8.) In one attempt to reach such a conclusion, Burtraw et al. (1997) estimate that the health benefits alone from reducing emissions exceed by seven times the cost of reduction, once this lower-cost trading regime was in place.

6.2 Global Warming

The environmental externality that could potentially cause the most harm to humans is global warming. The earth is heated by solar radiation that passes through our atmosphere and warms the earth's surface. The earth radiates some of the heat back into space, but a large portion is trapped by certain gases in the earth's atmosphere, like carbon dioxide and methane, which reflect the heat back toward the earth again. This phenomenon is called the **greenhouse effect** because a greenhouse works by letting in sunlight and trapping the heat produced from that light. The greenhouse effect is essential to life: without it, the earth would be about 60 degrees cooler, and life as we know it would end.[11]

greenhouse effect The process by which gases in the earth's atmosphere reflect heat from the sun back to the earth.

The problem is that human activity has been increasing the atmospheric concentration of greenhouse gases such as carbon dioxide and methane, and thus the magnitude of the greenhouse effect has risen. Since the industrial revolution, for example, the amount of carbon dioxide in the atmosphere has increased by about a third, to 800 billion metric tons of carbon—its highest level in 400,000 years (amounts of carbon dioxide are measured by what the carbon alone would weigh if in solid form, sort of like a chunk of coal). Most of this carbon dioxide has come from the use of fossil fuels such as coal, oil, and natural gas. By our use of fossil fuels, humans have contributed to the warming of the earth's atmosphere as reflected in the increase of surface temperatures by more than 1 degree Fahrenheit over the past 30 years, the most rapid increase in at least 1,000 years (see Figure 5-1, p. 121). Global snow cover has declined by 10% since the 1960s, and global sea levels have risen by one-third to two-thirds of a foot over the last century.



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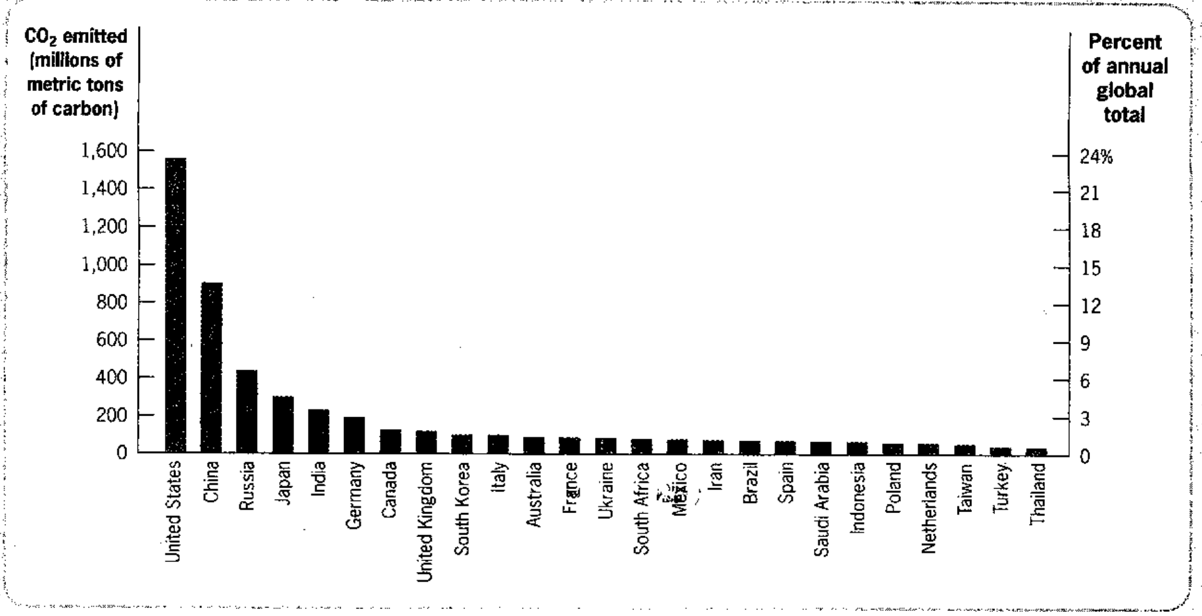
"Gentlemen, it's time we gave some serious thought to the effects of global warming."

[11] Congressional Budget Office (2003a).

More worrisome are projections for the next century that temperatures will increase by as much as 6 to 10 degrees Fahrenheit, a rate without precedent in the last 10,000 years.[12] A temperature rise of 6 degrees would lower global GDP in 2100 by over 10%, with India, Africa, and Western Europe seeing reductions of more than 15%.[13] As noted in the previous chapter, the global sea level could rise by almost three feet, increasing risks of flooding and submersion of low-lying coastal areas. Perhaps the most vivid short-run illustration of the damages of global warming was the destruction of the Ward Hunt ice shelf. This ice shelf was 80 feet thick and three times the size of Boston, making it the largest ice shelf in the Arctic, but in the summer of 2003, it split into two large pieces and many small islands, an event labeled "unprecedented" by scientists. Unprecedented, but perhaps not surprising: temperatures have been rising by 1 degree Fahrenheit per decade in the Arctic, and the thickness of this ice shelf had decreased by half since 1980.[14]

Figure 6-2 shows how much carbon dioxide the most polluting nations emit annually by burning fossil fuels, the main source of greenhouse gas emissions. (In

▪ FIGURE 6-2



Top 25 Fossil Fuel CO_2 Emitters in 2003 • The United States accounted for almost one-quarter of the entire stock of CO_2 emissions in 2003.

Source: Energy Information Administration (2005), Table H1.

[12] International Panel on Climate Change (2001).

[13] Nordhaus and Boyer (2000), Figure 4.4. The damage to India and Africa will come through the impact of global warming on human health, as a number of tropical diseases will be able to spread beyond their current boundaries. India's agricultural output will also likely suffer significant harm, as increased monsoon activity reduces output. Western Europe's agriculture and quality of life will likely suffer from drastic cooling that will occur because of changing ocean currents due to global warming.

[14] Revkin (2003).

the United States today, for example, fossil fuels account for about 85% of all the energy used.) The United States is currently responsible for nearly 25% of the planet's annual carbon dioxide emissions from fossil fuels, while Japan contributes only 5% of annual emissions. Developing countries like China and India also emit large quantities of greenhouse gases, but this is a relatively recent phenomenon. If we add up such emissions over the course of the twentieth century, we find that although developed nations have only 20% of the world's population, they are responsible for 80% of the total greenhouse gas emissions from fossil fuels.

Despite this unequal role in producing emissions, global warming is truly a global problem. Carbon emissions in Boston and Bangkok have the same effect on the global environment. Moreover, it is the stock of carbon dioxide in the air, not the level of yearly emissions, that causes warming. Global warming is therefore not a problem that can be immediately solved by cutting back on carbon use. Even if all nations ended their use of all fossil fuels today, it would take centuries to undo the damage done by the industrialization of the developed world. Thus, global warming is a complicated externality that involves many nations and many generations of emitters.

The Kyoto Treaty

International conferences to address the problem of global warming began in 1988. The peak of activity was a 1997 meeting in Kyoto, Japan, which was attended by over 170 nations. At that meeting, after intense negotiation, the 38 industrialized nations agreed to begin to combat global warming by reducing their emissions of greenhouse gases to 5% below 1990 levels by the year 2010.[15] These goals were written into a treaty that has since been ratified by 35 of the 38 signatory countries, and that went into effect in early 2005. A notable omission from the ratification list is the United States, which has shown no interest in signing on to this level of emissions reduction. Given the growth in the U.S. economy since the Kyoto treaty was signed, a reduction to 7% below 1990 levels would imply reducing projected emissions in 2010 by roughly 30%.[16] Nordhaus and Boyer (2000, Table 8.6) estimate that achieving the Kyoto targets would imply a present discounted value cost to the United States of $1.1 trillion (more than twice what the government spends on its largest program, Social Security, each year). By these authors' estimates, the United States would bear over 90% of the total world cost of meeting the Kyoto targets, even though it contributes only 25% of annual greenhouse gas emissions. The United States' share of the costs is so high because its emissions are forecast to grow so rapidly, and because its emissions are very costly to reduce due to continued reliance on coal-fired power plants (as opposed to

[15] This is an average that reflects a compromise among that set of nations; the United States, for example, agreed to reduce to 7% below 1990 levels. Also, the deadline is not exactly 2010: emissions must be reduced to that level on average over the 2008 to 2012 period.

[16] Estimate from United Nations Environment Programme at http://www.grida.no.

the natural gas or nuclear-powered plants more frequently used in other nations such as Japan, which produce much lower levels of greenhouse gases).

Can Trading Make Kyoto More Cost-Effective?

The cost figures just presented are enormous, and one can understand the reluctance of the United States to enter such a potentially costly agreement. But these estimates ignore a key feature negotiated into the Kyoto treaty, largely at the behest of the United States: **international emissions trading.** Under the Kyoto treaty, the industrialized signatories are allowed to trade emissions rights among themselves, as long as the total emissions goals are met. That is, if the United States wanted to reduce its emissions to only 1990 levels, rather than to 7% below 1990 levels, it could do so by buying emissions permits from another nation and using them to cover the reduction shortfall.

international emissions trading Under the Kyoto treaty, the industrialized signatories are allowed to trade emissions rights among themselves, as long as the total emissions goals are met.

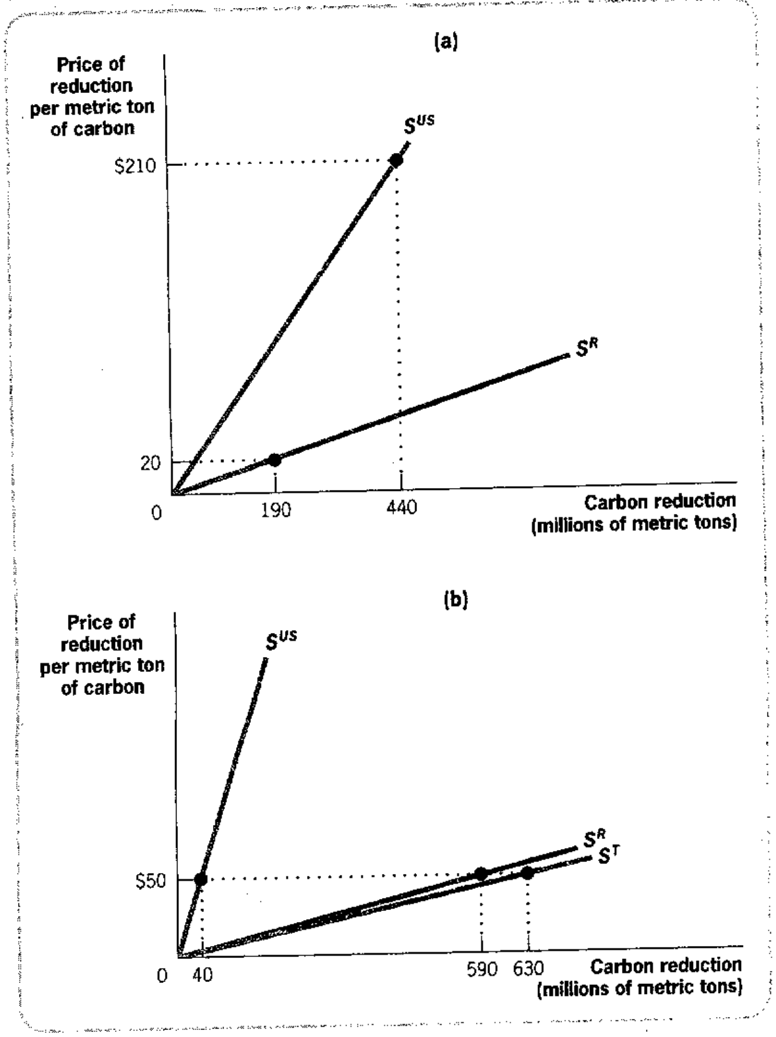
This is an important aspect of the treaty because there are tremendous differences across developed nations in the costs of meeting these goals, for two reasons. First, there are large differences in the rate of growth since 1990: the lack of economic (and thus emissions) growth in the 1990s in Russia, for example, implies that it will not be very costly for Russia to return to 1990 emissions levels. Second, growth has been more "environmentally conscious" in some nations than in others, so economic growth has not been as much accompanied by emissions growth in nations such as Japan that use more gas and nuclear-powered production. Thus, much as with our two-firm example in Chapter 5, the total costs of emissions reductions can be reduced if we allow countries with low costs of reduction, such as Russia, to trade with countries with high costs of reduction, such as the United States. By some estimates, such trading could lower the global costs of reaching the Kyoto targets by 75%.[17]

This point is illustrated in Figure 6-3 on page 160. This figure shows the market for carbon reduction, with millions of metric tons of carbon reduction on the x axis. There is a fixed target of carbon reduction in the Kyoto treaty for the United States at 7% below 1990 levels, a reduction of 440 million metric tons. The total worldwide mandated reduction under Kyoto is 630 million metric tons, so that the rest of the world has to achieve a net reduction of 190 million metric tons.

With no trading, shown in panel (a), nations would have to meet this target from their own supply of reduction opportunities. The reduction opportunities in the United States are represented by the supply curve S^{US}. This curve slopes upward because initial reduction opportunities are low cost: for example, plants that are close to energy efficient can be fitted with relatively cheap changes to become energy efficient. Costs rise as reduction increases, however: additional reductions may require replacing energy-inefficient but perfectly functional plants with newer ones at great cost.

[17] Nordhaus and Boyer (2000), Table 8.5.

■ **FIGURE 6-3**



The Benefits of Trading • The supply curve of reductions for the United States (S^{US}) is much steeper than that for the rest of the world (S^R). If the United States has to do all of its reductions by itself (panel a), it costs $210 per ton of reduction. In that case, the United States reduces by 440 million metric tons (mmt) and the rest of the world reduces by 190 mmt. If the United States and other nations can trade (panel b), then the relevant supply curve is S^T. In that case, the price per ton falls to $50, with the rest of the world reducing by 590 mmt and the United States reducing by only 40 mmt.

In this no-trading world, the marginal cost of achieving the Kyoto target of a reduction of 440 million metric tons (as measured by the S^{US} curve) is $210 per metric ton of carbon. For ease, we combine the rest of the world into one group with reduction opportunities represented by S^R in panel (a) of Figure 6-3. The S^R curve lies far below S^{US}, indicating that these nations have much lower marginal cost reduction opportunities. For those nations to reduce by 190 million metric tons would cost them only $20 per metric ton of carbon.

Now suppose that the United States can buy permits from Russia and other nations. In panel (b) of Figure 6-3, we can measure the aggregate supply curve to the world market by horizontally summing the two supply curves S^R and S^{US} to obtain the aggregate supply curve S^T. The cost of the worldwide required level of reduction of 630 million metric tons is $50 per ton, given this supply curve. This means that, with international trading, any reductions that cost more than $50 per ton can be offset by purchasing permits instead. At that price, the United States would choose to reduce its own emissions by 40 million metric tons (since any additional reduction costs more than the $50 price per permit), and buy the remaining 400 from other nations. Other nations would reduce their emissions by 590 million metric tons, the 190 million required plus the 400 million sold to the United States. The total cost of meeting the Kyoto target worldwide would now have fallen substantially: instead of most of the reduction being done at high cost in the United States, it would now be done at low cost elsewhere.

That is, by distributing the reduction from the high-cost United States to the low-cost other nations, we have significantly lowered the price of reductions worldwide. Note that, even though the marginal cost of reduction in other nations has risen, this is because they have moved up their supply curve: these other nations are happy to supply that higher level of reduction at $50 per metric ton (they are deriving substantial producer surplus from that transaction since most of their reduction costs much less than $50 per ton). The importance that U.S. environmental negotiators placed on negotiating this trading regime shows the extent to which environmentalists in the United States have internalized the lessons from the Acid Rain Program about the benefits of allowing flexibility in meeting environmental targets.

Participation of Developing Countries The trading story does not end with the developed nations of the world, however: by the year 2030, developing nations will produce more than half of the world's emissions, with China and India leading the way.[18] As a result, an agreement that does not ultimately include developing nations is doomed to failure as a mechanism for addressing global warming.

Moreover, including developing nations in such a plan adds flexibility and lowers the costs of meeting emission reduction targets. The cost of reducing emissions in developing countries is an order of magnitude lower than in the developed world. This is because it is much cheaper to use fuel efficiently as you develop an industrial base than it is to "retrofit" an existing industrial base to use fuel efficiently. By some estimates, if we had an international trading system that included developing nations, the cost to the developed world of complying with the Kyoto treaty would fall by another factor of four.[19] That is, with both international trading *and* developing country participation, the costs of meeting the Kyoto targets would be only one-sixteenth of their costs without these "flexibilities."

The developing nations wanted no part of this argument at Kyoto, however. They pointed out, rightly, that the problem that the world faces today is the result of environmentally insensitive growth by the set of developed nations. Why, they ask, should they be forced to be environmentally conscious and clean up the mess that the United States and other nations have left behind? This conflict must be resolved for an effective solution to this global problem.

[18] Nordhaus and Boyer (2000), Figure 7.7.
[19] Nordhaus and Boyer (2000), Table 8.5.

Ultimately, obtaining the participation of developing nations will likely involve some significant international transfers of resources from the developed to the developing world as compensation.

What Does the Future Hold?

The Kyoto treaty of 1997 was the most significant effort made to address the global externality of greenhouse gas emissions. Developments since that time, in particular the decision of the United States to reject the Kyoto treaty, do not bode well for short-term agreement on how to combat the problem of global warming.. Does this mean that international cooperation to combat global warming is impossible? Recent evidence, reviewed in the application, suggests that the nations of the world can come together to combat a global environmental threat, but only when that threat is urgent.

An important question for future global warming debates is whether the international community should continue with Kyoto's quantity-based policy or move toward a price-based policy that would include internationally coordinated taxes on carbon usage, as advocated, for example, by Nordhaus (2006). The uncertainty model presented in Chapter 5 clearly suggests that taxation would dominate regulation (even with trading) in this context. This is because the benefits of emission reduction are related to the existing stock of greenhouse gases in the atmosphere, so that the marginal benefits of any given emission reduction are constant: given the enormous boulder that must be moved to stop global warming, each additional person pushing on the boulder has a fairly constant effect. On the other hand, the marginal costs of emissions reduction are both uncertain and not constant across nations; for some countries reduction is low cost, while for others its expensive. As we learned in Chapter 5, in such a situation (that is, one with uncertain and varying marginal costs, with flat marginal benefits) taxation dominates regulation, because regulation can lead to excessive deadweight loss when emissions reduction gets very expensive. Price and quantity approaches could even be combined in the future by pairing the quantity goals with a "safety valve" rule that allows countries to reduce their required emission reductions if the cost gets too high, so that there is a price ceiling on quantity restrictions.

APPLICATION

The Montreal Protocol

An excellent example of international cooperation is the Montreal Protocol of 1987, which banned the use of chlorofluorocarbons (CFCs). CFCs were a popular chemical used in many facets of everyday life, including refrigerators, air conditioners, and spray cans. Their popularity partly derived from their very long life, but this longevity also led to a major environmental problem: CFCs were drifting into our stratosphere, and in the process of decaying were breaking down the ozone layer, which protects the earth from harmful UV-B radiation from the sun. As with global warming, this was a potentially enormous long-run problem: projections showed that, by 2050, ozone depletion would have reached 50–70% in the northern hemisphere, resulting in 19 million more cases of non-melanoma skin cancer, 1.5 million cases of melanoma cancer, and 130 million more cases of eye cataracts.[20]

Unlike global warming, the CFC problem was showing itself immediately and urgently: by the 1980s, a 25 million square kilometer hole had opened in the ozone layer over Antarctica! This hole spurred the international community to action, and in September 1987, the Montreal Protocol was adopted, aiming for complete phaseout of specified chemicals (mostly CFCs and halons) according to specified schedules. This agreement was ratified by 184 countries, and worldwide consumption of CFCs dropped from 1.1 million tons in 1986 to 64,112 tons in 2004.[21]

The result is that scientists predict the hole in the ozone layer will be biggest sometime in the next decade (as long-lived chemicals continue to diffuse upward into the stratosphere) but will then begin to recover and return to normal around 2050.

Thus, it may take some type of exciting and newsworthy event to spur action on global warming. The problem is that, unlike with CFCs, global warming will not be solved for centuries after emissions are greatly reduced. So if the world waits for a crisis to spur us into action, it may be too late. ◄

6.3 The Economics of Smoking

All externalities are not large-scale environmental problems. Some of the most important externalities are local and individualized. Many of these arise in the arena of personal health, and one of the most interesting is smoking.

Cigarette smoking is the single greatest self-imposed health hazard in the United States today. The number of cigarettes smoked has declined substantially over the past few decades, as shown in Figure 6-4 (page 164), yet almost one-fifth of Americans still smoke. This is despite the fact that smoking causes more than 438,000 deaths each year, *four times* as many as AIDS, motor vehicle accidents, homicide, and suicide combined. As Figure 6-5 (page 164) illustrates, smoking is the second-leading cause of death in the United States.[22] Worldwide, the problem is even worse. Of all persons alive today, 650 million will die of smoking-related disease. By 2020, 10 million persons will die annually from smoking-related disease. At that point, smoking will be the leading cause of death (not just preventable death) throughout the world.[23]

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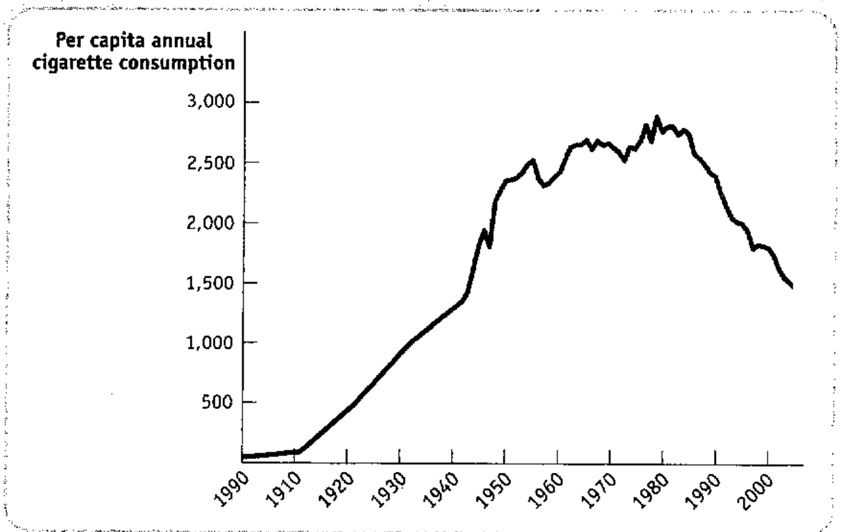
[20] United Nations Environment Programme (2003).

[21] United Nations Environment Programme (2006).

[22] Number of smoking-attributable deaths from Centers for Disease Control and Prevention (2005a); chart data from CDCP (2006b), Table C. In this chart, the share of deaths attributable to cancer, heart disease, and other illnesses excludes the share of illnesses that are smoking-related since those are included in the smoking category.

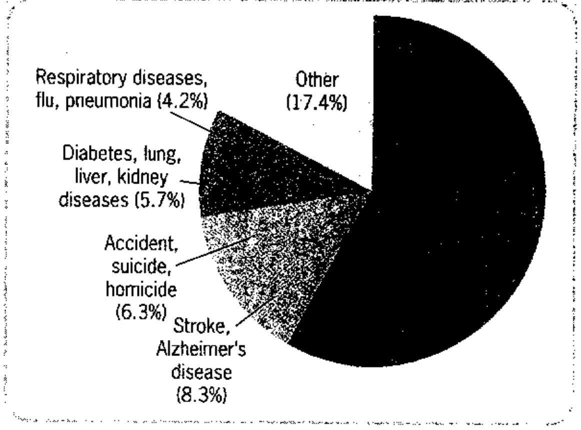
[23] World Health Organization. "Why Is Tobacco a Health Priority?" Accessed last on June 2, 2006, at http://www.who.int/tobacco/health_priority/en/index.html.

■ **FIGURE 6-4**



Per Capita Annual Cigarette Consumption, 1900–2004 • Cigarette consumption rose steadily throughout the first half of the twentieth century, flattened in the 1960s and 1970s, and began to decline sharply after 1980.

■ **FIGURE 6-5**



Leading Causes of Death, 2001 • Smoking-related deaths represent 18.1% of all deaths, more than other cancers combined and almost as much as other heart diseases.

Source: Centers for Disease Control and Prevention (2005a and 2006b).

Are these dire facts a cause for regulating smoking? Not in the view of traditional microeconomics. In the standard utility maximization model, any damage that individuals do to themselves from dangerous activities such as smoking results from a rational choice of trading off benefits against potential costs. The health hazards of smoking are now well known. The fact that smokers smoke given these risks, economists say, reveals their preference for the current pleasure of smoking over the distant costs of a shorter life.

Doesn't this argument ignore the fact that smoking is highly addictive? After all, leading experts on addiction rate nicotine as more addictive than either caffeine or marijuana, and in some cases, comparable to cocaine: among users of cocaine, about half say that the urge to smoke is as strong as the urge to use cocaine. Doesn't this mean that the damage that individuals do to themselves is a call to government action?

Once again, the answer from traditional economics is no. As postulated in a highly influential article by Becker and Murphy (1988), "rational addicts" understand that each cigarette they smoke today increases their addiction, leading them to smoke more tomorrow. As a result, when they buy a pack of cigarettes, they consider not only the cost of that pack but also the cost of all additional future packs that will now be purchased because their addiction has deepened. Moreover, the smoker understands that lighting up doesn't just

▪ TABLE 6-1

The Effects of Smoking: Externalities or Not?

Effect	Not an externality if . . .	An externality if . . .
Increased health care costs	Insurance companies actuarially raise premiums for smokers.	Many individuals are insured by entities that spread the health costs of smokers among all of the insured; also, the health costs of the uninsured are passed on to others.
Less-productive workers	Employers adjust individuals' wages according to productivity.	Employers do not adjust wages according to individual productivity, so that they must lower wages for all workers to offset productivity loss.
Increased number of fires	Smokers set fire only to their own property, requiring no help from the fire department, and insurance companies adjust premiums according to smoking status.	The fires damage nonsmokers' property, raise the cost of the local fire department, or raise fire insurance premiums for all.
Earlier deaths	Smokers do not pay Social Security taxes or would not incur medical costs later in life.	Nonsmokers save money because smokers die too early to collect full Social Security benefits and because their deaths reduce the high health costs near the end of life (a positive externality).
Secondhand smoke effects	The effects are minimal or smokers account for their families' utility when deciding to smoke.	The effects are serious and smokers do not account for their families' utility when deciding to smoke.

Cigarette smoking has a number of physical and financial effects, but in many cases they may not be externalities. The first column of this table lists examples of the effects of smoking. The second column discusses the situations under which these are not externalities, and the third column discusses the situations under which they are externalities.

reduce health through the current cigarette but through all the future cigarettes that will be consumed as a result of that addiction. If the smoker consumes the cigarette anyway, then this is a rational choice, and does not call for government intervention.

The Externalities of Smoking

The key public finance implication of the traditional economics approach is that the appropriate role for government is *solely a function of the externalities that smokers impose on others.* Like all other consumption decisions, smoking is governed by rational choice. That smokers impose enormous costs on themselves is irrelevant to public finance; only the costs smokers impose on others call for government action. Measuring the externalities from smoking is complicated, however, as we discuss next (and summarize in Table 6-1).

Increased Health Costs from Smoking By one estimate, smoking-related disease increases U.S. medical care costs by $75.5 billion, about 8% of the total cost of health care in the United States.[24] This enormous number alone does not, however, justify government intervention. Suppose that all individuals in society had health insurance that they purchased on their own, and that the

[24] American Cancer Society (2006).

price of that health insurance was set by insurance companies as a function of smoking status. Insurance companies would compute the extra amount they expect to spend on the medical care of smokers, and charge smokers a higher premium to compensate the insurance company for those extra costs. Such increases in insurance prices to compensate for expected expense differences are called **actuarial adjustments.** Actuarial adjustments *internalize the medical cost externality* from smoking. In this simplified model, there are no health externalities because smokers pay for the high medical costs associated with smoking through actuarial adjustments: society (in this case, the insurance companies) is fully compensated for the extra costs due to smoking through these higher premiums.

actuarial adjustments Changes to insurance premiums that insurance companies make in order to compensate for expected expense differences.

The external effects of increased health costs due to smoking arise because the real world deviates from this simplified example in three ways. First, insurance is not always actuarially adjusted for smoking behavior. At MIT, the price I pay for my group insurance is independent of my smoking behavior. If I smoke, and have high medical costs, then the insurance company will have to raise the premiums it charges to everyone at MIT by a small amount to compensate for this loss. In this case, I have exerted a negative externality on my coworkers, which I do not internalize because I do not fully pay the higher premiums associated with my smoking.

Quick Hint Externalities can be *financial* as well as *physical*. My smoking creates an externality because the social marginal benefit of my consumption of cigarettes is below my private marginal benefit by the extra amount that my coworkers have to pay for insurance.

Second, individuals who receive their insurance from the government do not pay higher premiums if they smoke. In this case, the negative externality occurs because the medical costs incurred by smokers are borne by all citizens through higher taxation. Finally, some individuals are uninsured and will not pay the cost of their medical care. Medical providers will typically make up these costs by increasing the amount they charge to other medical payers, exerting a negative financial externality on those payers.

Workplace Productivity There are many reasons why smokers may be less productive in the workplace: they may require more sick leave or more frequent breaks (for smoking) when at work. One study found that smokers impose $600–$1,100 per year in productivity and absenteeism costs on businesses, and another found that smokers miss 50% more work days each year due to illness than do nonsmokers.[25] Is this a negative externality to the firm? Once again, the answer is a qualified maybe. In this case, it depends on whether these workers' wages adjust to compensate for their lower expected productivity. That is, actuarial adjustments aren't necessarily found only in

[25] See Manning et al. (1991), Table 4-11 for absenteeism statistics and p. 139 for a literature review on cost estimates.

insurance markets; they may exist in labor markets as well. If wages fall to compensate the firm for a smoker's lower productivity, then the firm can internalize the productivity externalities associated with smoking. If not, these externalities will not be internalized.

Fires Smokers are much more likely to start fires than nonsmokers, mostly due to falling asleep with burning cigarettes. In 2000, for example, fires started by smokers caused 30,000 deaths and $27 billion in property damage worldwide.[26] Does this death and destruction represent an externality? If a smoker lived by himself on a mountain and burned down his house, killing himself, but with no damage to any other person, flora, or fauna, then there is no externality. But, in reality, externalities from such fires abound. There is the cost of the fire department that combats the fire; the damage that the fire may do to the property of others; and the increased fire insurance premiums that everyone must pay unless there is appropriate actuarial adjustment in the fire insurance market for smoking.

The "Death Benefit" An interesting twist on the measurement of smoking externalities is presented by the *positive* externalities for the taxpayer by the early deaths of smokers. Consider, for example, the Social Security program, which collects payroll tax payments from workers until they retire, and then pays benefits from that date until an individual dies. Smokers typically die around retirement age, so that they do not collect the retirement benefits to which their tax payments entitled them. In this situation, smokers are exerting a *positive financial externality* on nonsmokers: smokers pay taxes to finance the retirement benefits but do not live long enough to collect their benefits, leaving the government more money to pay benefits for nonsmokers. Thus, through the existence of the Social Security program, smokers benefit nonsmokers by *dying earlier.*

Moreover, the fact that smokers die earlier also offsets many of the medical cost effects of smoking. If smokers die at 65, then they won't impose large nursing home and other medical costs at very advanced ages. These avoided medical costs offset much of the additional medical costs from treatment for cancers and heart disease at younger ages.

Externality Estimates The effects of these four components, along with some other minor negative externalities, make the estimate of the external costs of smoking roughly $0.43 per pack in 2005 dollars.[27] This figure is sensitive to many factors, most importantly how one takes into account that the costs are often in the distant future while the benefits of smoking are current. Nevertheless, by most estimates the external cost of smoking is well below the average federal plus state cigarette tax in the United States, which is over $1 per pack. Of course, these estimates leave out another externality that is potentially important but very difficult to quantify: **secondhand smoke.**

secondhand smoke Tobacco smoke inhaled by individuals in the vicinity of smokers.

[26] Leistikow, Martin, and Milano (2000).
[27] Gruber (2001).

What About Secondhand Smoke? The damage done to nonsmokers by breathing in secondhand cigarette smoke is a classic externality because individuals do not hold property rights to the air. Without clearly defined property rights, complete Coasian solutions to this problem are not available. Yet the costs of secondhand smoke are not easily added to the list of external costs we have noted for two reasons. First, there is considerable medical uncertainty about the damage done by secondhand smoke. As a result, estimates of the externalities from secondhand smoke vary from $0.01 to $1.16 per pack![28]

Second, most of the damage from secondhand smoke is delivered to the spouses and children of smokers. If a smoking mother includes the utility of her family members in her utility function (maximizing *family* rather than just *individual* utility), she will take into account the damage she does to her husband and children by smoking. In this case, in making her choice to smoke, the smoker has decided that the benefits to her from smoking exceed the health costs both to herself *and* to her family members. When the externality is internalized in this way, the cost to other family members from being made ill must be offset by the large benefit the mother receives from smoking—or else she wouldn't smoke. On the other hand, if the smoking mother fails to fully account for the costs to her family members (fails to maximize family utility), then some of the damage she does to others will not be internalized, and should be counted in the externality calculation. Existing evidence suggests that family utility maximization is in fact incomplete, so these secondhand smoke costs are to some extent externalities.[29]

Should We Care Only About Externalities, or Do "Internalities" Matter Also?

The traditional economics approach suggests that the only motivation for government intervention in the smoking decision is the externalities that smokers impose on others, since any damage that smokers do to themselves has been accounted for in the smoking decision. But this model ignores some key features of the smoking decision that suggest that there may be other rationales for government intervention. Two such features are particularly important: the decision by youths to smoke and the inability of adults to quit. After reviewing these features, we will turn to how they challenge the traditional view of cigarette taxes based solely on externalities by suggesting that self-inflicted smoking damage matters for government policy as well.

Youth Smoking Of all adults who smoke, more than 75% begin smoking before their nineteenth birthday, but economics does not yet have a satisfactory model of the behavior of teenagers (as a matter of fact, neither do parents!).[30]

[28] Viscusi (1995), Table 11.
[29] See Lundberg, Pollack, and Wales (1997) for striking evidence against family utility maximization. This article shows that, in contrast to the family utility maximization model (where everyone cares equally about all the family members), shifting the control of household financial resources from husbands to wives significantly increases the expenditures made on behalf of children.
[30] In this section on internalities, all smoking facts come from Gruber (2001a) unless otherwise noted. For a broader analysis of the economics of risky behavior among youth, see Gruber (2001b).

The traditional model of smoking presumes that the decision to initiate this addictive behavior is made with a fully rational trade-off in mind between current benefits and future costs. If teens who begin to smoke do not correctly and rationally evaluate this trade-off, then government policy makers might care about the effect of the smoking decision on smokers themselves.

Indeed, there is some evidence that this monumental decision may not be made in the forward-looking fashion required by rational addiction models. A survey asked high school seniors who smoked a pack a day or more whether they would be smoking in five years and then followed the seniors up five years later. Among those who had said they would be smoking in five years, the smoking rate was 72%—but among those who said they would *not* be smoking in five years, the smoking rate was 74%! This result suggests that teens who smoke may not account for the long-run implications of addiction.

Adults Are Unable to Quit Smoking Even if They Have a Desire to Do So

Another key fact about smoking is that many adults who smoke would like to quit but are unable to do so. Consider the following facts:

- Eight in ten smokers in America express a desire to quit the habit, but many fewer than that actually do quit.
- According to one study, over 80% of smokers try to quit in a typical year, and the average smoker tries to quit every eight and a half months.
- 54% of serious quit attempts fail within one week.

These facts are worrisome because they hint that smokers may face a **self-control problem,** an inability to carry out optimal strategies for consumption. Economic theory assumes that individuals *can not only optimize their utility function, but that they can then carry out those optimal plans.* There is much evidence from psychology, however, that contradicts this assumption: individuals are often unable to carry out long-term plans that involve self-control when there are short-term costs to doing so. An excellent example of this is smoking, where there is a short-term cost of quitting (in terms of physical discomfort and perhaps mental distress), but a long-term health benefit. Other examples include retirement savings (short-term cost in terms of forgone consumption today, but long-term benefits in terms of a higher standard of living in retirement), or whether to diet and/or exercise (short-term costs in terms of less food or more work today, but long-term benefits in terms of a longer life). In many arenas, individuals appear unable to control their short-term desires for their own longer-term well-being.

self-control problem An inability to carry out optimal strategies for consumption.

There are two types of evidence for the existence of self-control problems. The first is from laboratory experiments in psychology. In laboratory settings, individuals consistently reveal that they are willing to be patient in the future, but are impatient today, the defining characteristics of self-control problems. A person with self-control problems has the right long-run intentions (he rationally optimizes his utility function given his budget constraint), but he just can't carry them out. For example, in one experiment, most people preferred a check for $100 they could cash today over a check for $200 they could cash two years from now. Yet the same people prefer a $200 check eight years from now to a $100 check six years from now, even though this is the *same choice*—it's just six years in the future.[31] This is consistent with self-control problems: individuals are willing to be patient in the future, but not today when faced with the same choice.

commitment devices Devices that help individuals who are aware of their self-control problems fight their bad tendencies.

The second type of evidence for self-control problems is the demand for **commitment devices.** If individuals have self-control problems and are aware of those problems, they will demand some type of device that helps them fight these problems. And the search for such commitment devices is the hallmark of most recommended strategies for quitting smoking: people regularly set up systems to refrain from smoking by betting with others, telling others about the decision, and otherwise making it embarrassing to smoke. These practices help individuals combat their self-control problems by raising the short-run costs of smoking to offset the short-run benefits of smoking. The use of self-control devices is widespread in other arenas as well: individuals set up "Christmas Clubs" at their banks to make sure they have enough money to buy Christmas presents, and they buy memberships at sports clubs to commit themselves to work out when it would generally be cheaper to just pay each time they go.[32]

Implications for Government Policy Both irrationalities among youth smokers and self-control problems among older smokers seem to be sensible features of any model of the smoking decision: we all know (or were) irrational youth, and we all know (or are) individuals with problems of self-control. Yet, these sensible psychological additions to the standard economic model have dramatic implications for government policy, because in either case it is not just the external damage from smoking that matters for government intervention, but also some of the damage that smokers do to themselves. If smokers make mistakes when they are young, or would like to quit but cannot, the damage from smoking is an **internality,** which refers to the damage one does to oneself through adverse health (or other) behavior. This internality justifies government regulation of smoking in the same way that externalities do in the traditional model. The government is once again addressing a failure; in this case it is not an externality on others but rather a cost imposed on one's long-run health by one's short-run impatience or teen irrationality. If the government can make individuals better off in the long run by addressing short-run failings, then it can increase efficiency as if it were correcting a market failure.

internality The damage one does to oneself through adverse health (or other) behavior.

The stakes are large here. While the damage that smokers do to others is, on net, small, the damage that smokers do to *themselves* is enormous. Consider just one aspect of that damage: shortened lives. The average smoker is estimated to live about six fewer years than nonsmokers. A year of life is typically valued by economists at about $200,000 (using methods discussed in more detail in Chapter 8). At this estimate, the value of life lost from smoking is about $35 per pack! This is an enormous figure, on the order of 100 times larger than the typical estimate of the external damage done by smoking.

[31] Ainslie and Haslam (1992).
[32] DellaVigna and Malmendier (2004).

The government has several policy tools at its disposal for addressing internalities. One tool is information about the health hazards of smoking. Much of the large decline in smoking over the past 30 years has been traced to the release of information about the dangerous health implications of smoking. Information about long-run health effects will not, however, effectively combat problems of self-control or teen irrationality.[33]

An excellent commitment device available to the government is taxation, which raises the price of cigarettes to smokers. A large body of evidence shows that smokers are fairly sensitive to the price of cigarettes, with smoking falling by about 5% for each 10% rise in prices (and by even more among especially price-sensitive youth smokers). By raising taxes, the government can force smokers to face higher costs that lower their smoking, providing the desired self-control.[34] Gruber and Koszegi (2004) calculate that, for the type of self-control problems documented in laboratory experiments, the optimal tax would be on the order of $5 to $10 per pack, above and beyond any taxes imposed to combat externalities. This is a high level that is well above taxation rates today.

The notion that government policy should be determined not just by externalities but by internalities as well is a major departure from traditional microeconomic policy analysis. As such, much more research is needed to decide how large internalities really are. Nevertheless, the enormous health costs of smoking ($35 per pack) suggest that, even if such internalities are small, they might justify large government interventions.

6.4 The Economics of Other Addictive Behaviors

While cigarette smoking is a particularly interesting application, it is by no means the only health behavior where externalities (or internalities) potentially cause market failure. We briefly consider three others.

Drinking

Alcohol consumption presents an interesting alternative example to cigarette smoking. On the one hand, the externalities associated with alcohol consumption are much larger than those associated with smoking. This is largely because the major externality associated with alcohol consumption is damage due to drunk driving. Over 17,000 persons per year are killed, and half a million more are injured due to alcohol-related automobile accidents in the

[33] My child's school has recognized the ineffectiveness of warning youths about the very-long-run risks of smoking. His recent antismoking bookmark had ten reasons not to smoke, and only one was long-term health risks; the other nine were short-term costs such as higher likelihood of acne or worse sports performance. These are clearly less important than early death from a long-run perspective, but the bookmark serves the purpose of making youths realize short-run costs that offset the short-run benefits of smoking.

[34] Indeed, Hersch (2005) finds that smokers who plan to quit smoking are much more supportive of regulations on smoking than are other smokers.

United States.[35] Economists assess the years of life lost from these accidents at a very high value (on the order of $120 billion per year). Even though the drunk driver may lose his license and see his insurance premiums rise, he is unlikely to bear the full costs to society of his action. The central estimate for the externalities due to drinking are 80¢ per ounce of ethanol (pure alcohol), which is much higher than current alcohol taxes that amount to only 9 to 24¢ per ounce of ethanol, depending on the type of drink (since taxes per ounce of ethanol vary across beer, wine, and other alcoholic drinks).[36]

These figures do not include another potentially important externality from drinking: the increased tendency toward violence and crime. Twenty-five percent of violent crimes, and 40% of domestic abuse cases, involve victims who report that the perpetrator had been drinking before committing the crime.[37] A series of articles by Sara Markowitz and colleagues document strong effects of anti-alcohol policies (such as higher taxes on alcohol) in lowering violence, crime, risky sexual behavior, and sexually transmitted diseases.[38] Once again, if this behavior only involves family members, it may or may not be an externality; when it involves others, such as through criminal acts, the behavior is clearly an externality.

The internalities due to drinking may be much smaller than those due to smoking, however. Drinking in small quantities, while it may impair one's driving, may actually be good for long-run health. And it is only a small share of drinkers who do damage to their health and otherwise harm themselves by drinking. Thus, the major rationale for government regulation of drinking is the standard one, from externalities.

The appropriate role for government in regulating drinking is difficult because the externalities due to drinking arise from the small share of drinking that results in drunk driving and violence. In theory, the optimal policy would target drunk driving and violence with steeper fines and penalties. But it is impossible to realistically raise the cost of drunk driving or violence enough to account for the externalities of that activity. At the other extreme, raising taxes on all alcohol consumption is a very blunt instrument that will lower drinking too much among those who aren't going to drive drunk or commit violent acts, and not enough among those who are at risk for driving drunk or alcohol-related violence. Nevertheless, given the enormous damage done by drinking, higher alcohol taxes would raise social welfare overall, relative to a system that leaves taxes at a level so far below the externalities of drinking.

Illicit Drugs

Another addictive behavior that raises government concern is the use of illicit drugs, such as marijuana, cocaine, ecstasy, and heroin. In the United States, as in most countries, the government regulates these activities by prohibiting

[35] National Highway Traffic Safety Administration (2005).
[36] Manning et al. (1989).
[37] U.S. Department of Justice (1998).
[38] See for example Markowitz and Grossman (1999), Markowitz (2000a, b), Grossman, Kaestner, and Markowitz (2004), and Markowitz, Kaestner, and Grossman (2005).

illicit drug consumption, subject to criminal penalty. This is a particularly interesting case because most of the externalities associated with illicit drugs arise *because* of their illegality. Indeed, legal consumption of some illicit drugs is likely to have much lower externalities than consumption of alcohol. Thus, the rational addiction model would suggest that there is no more call for regulating illicit drug use than for regulating smoking. As the famous economist Milton Friedman wrote in 1972, in advocating the legalization of drugs, "The harm to us from the addiction of others arises almost wholly from the fact that drugs are illegal. A recent committee of the American Bar Association estimated that addicts commit one-third to one-half of all street crime in the U.S. Legalize drugs, and street crime would drop dramatically."[39]

Yet, despite this argument, drug legalization remains a radical idea in America and in most nations. Thus, policy makers clearly don't believe that the rational addiction model applies equally to illicit drugs and other potentially addictive activities such as drinking and smoking. For illicit drugs, but not for smoking and drinking, the government appears to have concluded that individuals are not making the right long-term decisions for themselves—otherwise it is difficult to rationalize the public policies pursued in most industrialized nations.

Obesity

A potential health externality that has recently attracted significant attention in the United States and elsewhere is obesity. There has been an enormous rise in obesity in the United States: the share of the adult population classified as obese has risen from 13% in 1960 to 31% in 2002. Indeed, the fastest-growing public health problem in the U.S. today is *diabetes,* a disease whereby the body is not able to regulate its glucose (sugar) intake. Diabetes is a progressive and often fatal disease with no known cure. It can attack every organ in the body, resulting in higher risk of heart failure, stroke, and poor circulation, which can lead to amputation. The number of diabetics has doubled in the past decade, and it is projected that one in three children born in 2000 will have diabetes. The two biggest factors driving the rise in diabetes are the rise in obesity and inactive lifestyles in the U.S.

Recent studies have suggested that both the external costs of obesity (in terms of government health costs) and the internal costs of obesity (in terms of shortened lives and lower quality years of life) may exceed those of either cigarettes or alcohol.[40] Thus, under either traditional models or models that take into account self-control problems, there may be a large role for the government in addressing this problem.

Using tax policy to reduce obesity in the United States, however, is a very complicated task, because there is a very complicated relationship between different types of food consumption and health. As Rosin (1998) writes, "Measuring fat content is not always practical. Hamburger meat has a certain

[39] Friedman (1972).
[40] Centers for Disease Control and Prevention (2005b), Table 73.

percentage of fat, but most of it would melt away during grilling. And what about sugary no-fat snacks such as soda and candy?" This complicated relationship suggests that the most straightforward approach to addressing the costs of obesity would be to directly tax body weight (a "fat tax"), or to perhaps subsidize weight loss (a "skinny subsidy")!

Summary

In summary, regulating other health behaviors raises many similar issues to those we raised for smoking. For drinking and obesity, however, existing taxes are already so far below the level of negative externalities that assessing the role of self-control problems and internalities is not critical: virtually any economic model would imply that if these externality calculations are correct, taxes should be higher. Yet there are difficult issues in raising taxes in both cases, ranging from the fact that a moderate amount of consumption may actually be good for people (clearly so in the case of food!) to the fact that it is difficult to appropriately design taxes to target the externality.

6.5 Conclusion

This chapter has shown that the externality theory developed in Chapter 5 has many interesting and relevant applications. Public finance provides tools to help us think through the regulation of regional externalities such as acid rain, global externalities such as global warming, and even the "internalities" of smoking. Careful analysis of public policy options requires discriminating truly external costs from costs that are absorbed through the market mechanism, understanding the benefits and costs of alternative regulatory mechanisms to address externalities, and considering whether only externalities or also "internalities" should count in regulatory decisions.

▶ HIGHLIGHTS

- Acid rain is a clear negative externality exerted primarily by power plants on wildlife, trees, structures, and (through associated particulate emissions) human health.
- The original Clean Air Act significantly (but inefficiently) reduced the amount of particulates in the air (and thus reduced acid rain). Regulation became much more efficient with the trading regime imposed by the 1990 amendments to the act.
- Global warming is a difficult problem because the effects are truly global and very long lasting.
- The Kyoto treaty would be costly (for the United States) first step in addressing global warming, but trading and developing country participation could lower costs significantly.
- The net external costs of smoking are fairly low, suggesting a limited government role under the traditional model. Alternative models where consumers have self-control problems suggest that the government role may be larger.
- Other activities such as alcohol consumption and obesity have much larger externalities, but it is difficult to design regulatory mechanisms to target the exact source of the externality (drunk driving and fat consumption, respectively).

▶ QUESTIONS AND PROBLEMS

1. Some people were concerned that the 1990 amendments to the Clean Air Act would generate "hot spots" of pollution—localized areas with very high concentrations of pollutants. Why might the amendments lead to such "hot spots"? Are these "hot spots" necessarily a bad thing from an overall social welfare perspective? Explain.

2. The National Institute on Drug Abuse describes six-year trends in teenage smoking, drinking, and other drug use on the Web at http://www.nida.nih.gov/infofax/hsyouthtrends.html. According to this site, for which age groups have the changes in the rates of teenage smoking and drinking been most pronounced?

3. Think about the major ways in which acid rain causes damage, such as through forest erosion, property damage, reduced visibility, and adverse health outcomes. Which of these costs are highly localized and which are borne by society more broadly? Explain.

4. Many towns and cities in the northeast and west coasts have recently passed bans on smoking in restaurants and bars. What is the economic rationale behind these bans? Would there be similar rationales for banning smoking in automobiles? Apartment buildings? Houses?

5. Think about the concerns about the original 1970 Clean Air Act described in the text. To what degree did the 1990 amendments to the act address these concerns? Explain your answer.

6. In which way could smoking exert a *positive* externality on others?

7. Some observers argue that since carbon dioxide and temperature levels have been much higher in Earth's history than they are today, the current concerns about the human contribution to global warming are overblown. How would you empirically test this argument?

8. Nordhaus and Boyer (2000) estimated that the United States would bear over 90% of the total world cost of achieving the Kyoto targets for greenhouse gas emission reductions. Explain how this can be when the U.S. produces only about a quarter of the world's greenhouse gasses.

9. Evans, Farrelly, and Montgomery (1999) found evidence that workplace smoking bans substantially reduce overall rates of smoking, particularly for those people with longer work weeks. Why should workplace smoking bans be particularly influential in affecting the behavior of people who work long hours?

10. Congressman Snitch argues that since obesity causes so many serious health problems, fatty foods should be regulated. Do you agree with him?

The e icon indicates a question that requires students to apply the empirical economics principles discussed in Chapter 3 and the Empirical Evidence boxes.

▶ ADVANCED QUESTIONS

11. Why does Chay and Greenstone's (2003) approach to measuring the effects of acid rain reduce the identification problems associated with more "traditional" approaches?

12. Imagine that it is 1970, and your parents are in college, debating the merits of the Clean Air Act of 1970. Your father supports the act, but your mother says that since it only covers new plants, it might actually make the air dirtier.
    a. What does your mother mean by her argument?
    b. How would you construct an empirical test to distinguish between your parents' hypotheses?

13. Caffeine is a highly addictive drug found in coffee, tea, and some soda. Unlike cigarettes, however, there have been very few calls to tax it, to regulate its consumption, or limit its use in public places. Why the difference? Can you think of any economic arguments for regulating (or taxing) its use?

14. When Wisconsin had lower drinking ages than its neighboring states, it experienced higher levels of alcohol-related crashes in its border counties than in other counties in its interior. What does this finding imply for the spillover effects of the policies of one state (or country) on other jurisdictions?

15. In Becker and Murphy's "rational addicts" model, smokers are perfectly aware of the potential for smoking to cause addiction, and they take this into account when deciding whether or not to smoke. Suppose a new technology—such as a nicotine patch—is invented that makes quitting smoking much easier (less costly) for an addict. If Becker and Murphy's model is correct, what effects would you expect this invention to have on people's smoking behavior? Would your answer be different for young people than for older people?

7 Public Goods

The city of Dhaka, Bangladesh, has a garbage problem. Every few days, residents of the various Dhaka neighborhoods bring their trash to large dumpsters in central areas or smaller dumpsters along their local streets. In theory, municipal employees then collect the garbage and cart it off for disposal. In practice, however, those employees often fail to show up, leaving the garbage to rot in the streets and residents to fume in frustration.

An economist might wonder why the residents of Dhaka don't simply scrap the current system of public trash collection and instead pay a private service to pick up their trash. In this way, the free market might solve Dhaka's problems. The trouble is that private trash collection, financed by a voluntary fee paid by neighborhood residents, faces the classic *free rider problem* introduced in Chapter 5: any resident could continue to throw his trash in the dumpsters, and then refuse to pay his share of the trash collection fee, with the hope that his neighbors would pick up the costs for him. If his neighbors cover the cost of collection, this free rider gets all the benefits of trash collection but pays none of the costs. Yet, if some in the neighborhood free ride, others will feel exploited by paying to have their non-paying neighbors' trash picked up; these residents might decide not to pay either. Eventually, the number of free riders might grow large enough that the town would not be able to raise sufficient funds to finance the trash collection from a private company. For this reason, only about 50 of Dhaka's 1,100 neighborhoods have been able to replace the municipal trash collection with private collection financed by voluntary trash collection fees.[1]

The problems faced by the city of Dhaka illustrate the difficulties of effectively addressing the free rider problem through a private mechanism. Goods that suffer from this free rider problem are known in economics as *public goods,* and they are the focus of this chapter. We begin by defining *public goods* and determining the optimal level of their provision. We then turn to the first

[1] Pargal et al. (2000).

▪ TABLE 7-1

Defining Pure and Impure Public Goods

		Is the good rival in consumption?	
		Yes	**No**
Is the good excludable?	Yes	Private good (ice cream)	Impure public good (cable TV)
	No	Impure public good (crowded city sidewalk)	Pure public good (national defense)

Whether a good is private or public depends on whether it is rival and excludable. Pure private goods such as ice cream are both rival and excludable. Pure public goods such as national defense are neither rival nor excludable. Goods that are rival but not excludable, and vice versa, are impure public goods.

question of public finance and ask if the government should be involved in the provision of public goods. We show that the private sector is in fact likely to underprovide public goods due to the free rider problem. Sometimes, however, private actors successfully provide public goods, so we discuss the factors that make private provision successful.

We then discuss the public provision of public goods. In principle, the government can simply compute the optimal amount of a public good to provide, and provide that level. In practice, however, the government faces several difficulties in providing the optimal level of public goods. First, when private parties are already providing the public good, government provision may simply *crowd out* this private provision so that the total amount of the public good provided does not rise. Second, measuring the actual costs and benefits of public goods (which is required for determining optimal public goods provision) is difficult. Finally, determining the public's true preferences for public goods, and aggregating those preferences into an overall decision on whether to pursue public goods projects, raises a variety of challenges.

This chapter begins our section on public goods provision. Chapters 8 and 9 provide details on the problems of measuring the costs and benefits of public projects (*cost-benefit analysis*), and on the difficulties of effectively translating voters' preferences for public projects into public policy (*political economy*). Chapter 10 discusses the local provision of public goods and raises the important question of whether competition across localities can solve the public goods provision problems raised in Chapters 7–9. Finally, Chapter 11 focuses on one of the most important public goods provided in the United States: education.

pure public goods Goods that are perfectly non-rival in consumption and are non-excludable.

non-rival in consumption One individual's consumption of a good does not affect another's opportunity to consume the good.

non-excludable Individuals cannot deny each other the opportunity to consume a good.

impure public goods Goods that satisfy the two public good conditions (non-rival in consumption and non-excludable) to some extent, but not fully.

7.1 Optimal Provision of Public Goods

Goods that are **pure public goods** are characterized by two traits. First, they are **non-rival in consumption:** that is, my consuming or making use of the good does not in any way affect your opportunity to consume the good. Second, they are **non-excludable:** even if I want to deny you the opportunity to consume or access the public good, there is no way I can do so. These are fairly strong conditions, and very few goods meet these conditions in practice. Most of the goods we think of as public goods are really **impure public goods,** which satisfy these two conditions to some extent, but not fully.

Table 7-1 shows possible combinations of public good characteristics. Goods that are both excludable and rival are pure private goods. Private goods such as ice cream are completely rival (once you eat an ice cream cone, I cannot consume that ice cream cone at all) and they are completely excludable (you can simply refuse to sell me an ice cream cone).

There are two types of impure public goods. Some goods are *excludable, but not rival.* The best example here is cable television: the use of cable TV by others in no way diminishes your enjoyment of cable, so consumption is nonrival. It is, however, possible to exclude you from consuming cable TV: the cable company can simply refuse to hook you up to the system. Other goods, such as walking on a crowded city sidewalk, are *rival but not excludable.* When you walk on a crowded city sidewalk, you reduce the enjoyment of that walking experience for other pedestrians, who must now fight against even more foot traffic. Yet it would be very difficult for any city to exclude individuals from using the sidewalk!

Pure public goods are rare because there are few goods that are both not excludable and not rival. A classic example of a pure public good is national defense. National defense is not rival because if I build a house next to yours, my action in no way diminishes your national defense protection. National defense is not excludable because once an area is protected by national defense, everyone in the area is protected: there is no way the government can effectively deny me protection since my house is in a neighborhood with many other houses. Other classic examples of pure public goods include lighthouses and fireworks displays.

It is helpful to think about a public good as one with a large positive externality. If I set off fireworks high into the sky, it benefits many more people beyond myself, because many people will be able to see the display. I am not compensated for other people's enjoyment, however: I can't exclude others from seeing the fireworks, so I can't charge them for their enjoyment.

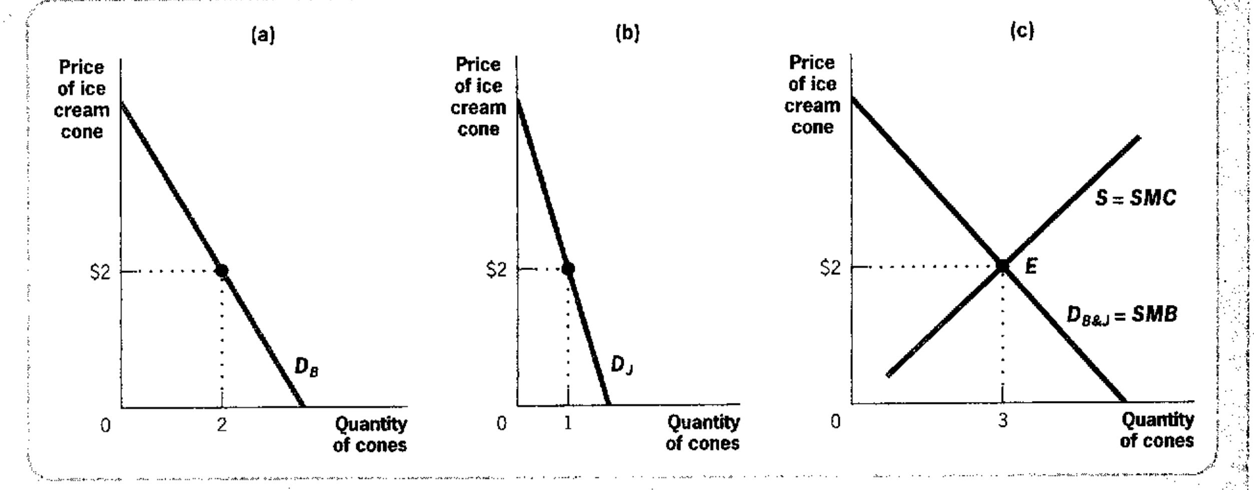
Optimal Provision of Private Goods

Before we model how to determine the optimal quantity of public goods to provide, let's review the conditions for optimal provision of private goods. Imagine that there are two individuals, Ben and Jerry, who are deciding between consuming cookies and ice cream, two pure private goods. For simplicity, suppose that the price of cookies is $1.

Quick Hint A convenient modeling tool in economics is the **numeraire good,** a good for which the price is set at $1. This tool is convenient because all choice models are technically written about the choice between goods, not the choice of a particular good. As a result, what matters for modeling the demand for any good (such as ice cream) is its price relative to other goods (such as cookies), not the absolute level of its price. By setting the price of cookies to $1, we make the analysis easier by making the absolute and relative price of ice cream equal.

numeraire good A good for which the price is set at $1 in order to model choice between goods, which depends on relative, not absolute, prices.

■ **FIGURE 7-1**



Horizontal Summation in Private Goods Markets • In private goods markets, we horizontally sum the demands of Ben and Jerry to get market demand for ice cream cones. If Ben demands 2 ice cream cones at $2, and Jerry demands 1 ice cream cone at $2, then at a market price of $2 the quantity demanded in the market is 3 ice cream cones.

Figure 7-1 shows the analysis of the market for ice cream cones. Panels (a) and (b) show Ben's and Jerry's individual demand curves for ice cream cones; that is, the number of ice cream cones that each man would demand at each price. Panel (c) shows the market demand curve, the horizontal sum of the two individual demands: for every price of ice cream cones, we compute Ben's demand and Jerry's demand, and then add them to produce a total market demand. At $2, Ben would like two ice cream cones, and Jerry would like one, for a total market demand of three cones. As we learned in Chapter 5, the demand curve in the final panel of Figure 7-1 also represents the *social marginal benefit (SMB)* of ice cream consumption, that is, the value to society from the consumption of that cone.

The market supply curve for ice cream represents the marginal cost of producing ice cream cones for a firm. As discussed in Chapter 5, in a market with no failures, this curve also represents the *social marginal cost (SMC)* of ice cream production, the cost to society from the production of that cone. In a private market, then, equilibrium occurs where $SMB = SMC$, the point at which supply and demand intersect. In Figure 7-1, equilibrium is at point E: at a price of $2, the market demands three ice cream cones, which are supplied by the firm.

A key feature of the private market equilibrium is that *consumers demand different quantities of the good at the same market price.* Ben and Jerry have different tastes for ice cream, relative to cookies. The market respects those different tastes by adding up the demands and meeting them with an aggregate supply. In this way, Ben and Jerry can consume according to their tastes. Since Ben likes ice cream more than Jerry, he gets two of the three cones that are produced.

It is also useful to represent this equilibrium outcome mathematically. Recall from Chapter 2 that an individual's optimal choice is found at the tangency between the indifference curve and the budget constraint. This is the point at which the *marginal rate of substitution* between ice cream cones and cookies (the rate at which consumers are willing to trade ice cream cones for cookies) equals the *ratio of the prices* of ice cream cones and cookies. That is, Ben and Jerry each consume ice cream cones and cookies until their relative marginal utilities from the consumption of these products equal the relative prices of the goods. The *optimality* condition for the consumption of private goods is written as:

(1) $$MU^B_{ic}/MU^B_c = MRS^B_{ic,c} = MRS^J_{ic,c} = P_{ic}/P_c$$

where MU is marginal utility, MRS is the marginal rate of substitution, the superscripts denote Ben (B) or Jerry (J), and the subscripts denote ice cream cones (ic) or cookies (c). Given that the price of cookies is \$1, and the price of an ice cream cone is \$2, then the price ratio is 2. This means that, in equilibrium, each individual must be indifferent between trading two cookies to get one ice cream cone. Ben, who likes ice cream more, is willing to make this trade when he is having two ice cream cones. But Jerry, who likes ice cream less, is only willing to make this two cookies for one ice cream cone trade at his first cone; after this, he isn't willing to give away two more cookies to get one more ice cream cone.

On the supply side, ice cream cones are produced until the marginal cost of doing so is equal to the marginal benefit of doing so, which, in this competitive market, is equal to the price. Thus, equilibrium on the supply side requires:

(2) $$MC_{ic} = P_{ic}$$

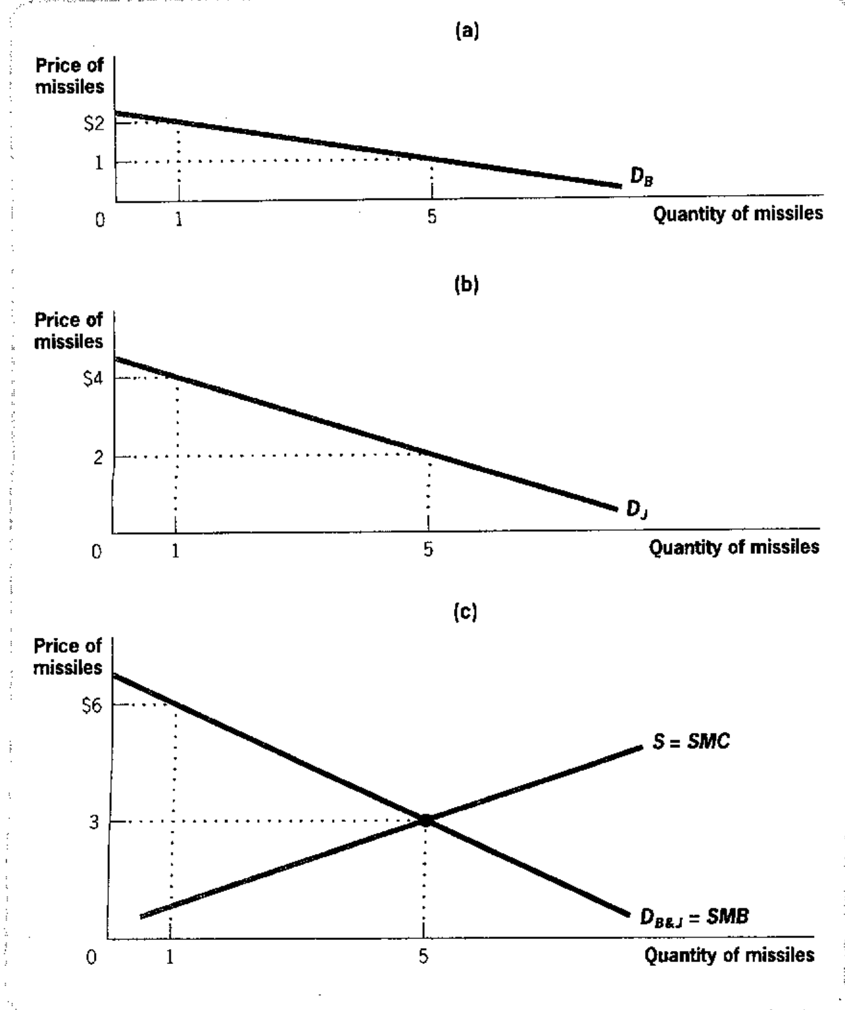
Recall that we have set P_c = \$1. Thus, we have from equation (1) that $MRS = P_{ic}$, and we have from equation (2) that $MC = P_{ic}$. In equilibrium, therefore, $MRS = MC$.

The private market equilibrium is also the social-efficiency-maximizing choice (the point that maximizes social surplus). This is because when there are no market failures, the MRS for any quantity of ice cream cones equals the social marginal benefit of that quantity; the marginal value to society is equal to the marginal value to any individual in the perfectly competitive market. Similarly, when there are no market failures, the MC for any quantity of ice cream cones equals the social marginal cost of that quantity; the marginal cost to society is equal to the marginal cost to producers in a perfectly competitive market. Thus, at the private market equilibrium $SMB = SMC$, which is the condition for efficiency we derived in Chapter 5 for efficiency maximization: the efficiency-maximizing point is the one where the marginal value of consuming the next unit to any consumer is equal to the marginal cost of producing that additional unit.

Optimal Provision of Public Goods

Now, imagine that Ben and Jerry are choosing not between ice cream cones and cookies but between missiles (a public good) and cookies. Once again, the

■ FIGURE 7-2



Vertical Summation in Public Goods Markets • For public goods, we vertically sum the demands of Ben and Jerry to get the social value of the public good. If Ben is willing to pay $1 for the fifth missile, and Jerry is willing to pay $2 for the fifth missile, then society values that fifth missile at $3. Given the private supply curve for missiles, the optimal number of missiles to produce is five, where social marginal benefit ($3) equals social marginal cost ($3).

price of cookies is set equal to $1. A difference between missiles and ice cream cones is that individuals cannot tailor their own specific consumption of missiles. Because missiles are a public good, whatever amount is provided must be consumed equally by all. This characteristic of the market for public goods turns the private market analysis on its head, as shown in Figure 7-2. Each person is now forced to choose a common quantity of the public good. Because Ben and Jerry have different tastes for missiles and cookies, they will be willing to pay different prices for this common quantity. Ben has a very flat demand for missiles; he is willing to pay only $2 for the first missile and $1 for the fifth missile (panel (a)). Jerry has a steeper demand, and is willing to pay $4 for the first missile and $2 for the fifth missile (panel (b)).

Whatever number of missiles is chosen applies to Ben and Jerry equally, since missiles are a public good. To arrive at the market demand for missiles, we do not sum horizontally, as with private goods (where we sum the individual quantities demanded at the given market price). Instead, we sum *vertically* by adding the prices that each individual is willing to pay for the fixed market quantity. Ben and Jerry are together willing to pay $6 for the first missile, but their willingness to pay declines as the number of missiles increases, so they are only willing to pay $3 for the fifth missile. This vertically summed demand curve is shown in panel (c) of Figure 7-2.

Panel (c) also shows a supply curve for missiles, which equals their marginal cost of production. The socially optimal level of production is the intersection of this supply with the vertically summed demand. That is, given that any missiles that are provided protect both Ben and Jerry, the producer should consider the *sum* of their valuations (their willingness to pay) in making its production decision. The resulting socially optimal level of production is five missiles.

Once again, a mathematical exposition helps clarify the mechanism underlying this result. The marginal missile is worth $MRS^B{}_{m,c}$ to Ben and $MRS^J{}_{m,c}$ to Jerry, so its total value to society is $MRS^B{}_{m,c} + MRS^J{}_{m,c}$. The social marginal benefit (*SMB*) of the next missile is the sum of Ben and Jerry's marginal rates of substitution, which represent their valuation of that missile. The social marginal cost (*SMC*) is the same as earlier: it is the marginal cost of producing a missile. Thus, the social-efficiency-maximizing condition for the public good is:

$$MRS^B{}_{m,c} + MRS^J{}_{m,c} = MC \tag{3}$$

Social efficiency is maximized when the marginal cost is set equal to the *sum of the MRSs, rather than being set equal to each individual's MRS.* For private goods, it is optimal for firms to produce until the marginal cost equals the benefit to the marginal consumer, and that is the private competitive market outcome. For public goods, however, it is socially optimal for firms to produce until the marginal cost equals the benefit to *all* consumers combined. This is because the private good is rival: once it is consumed by any one consumer, it is gone. The public good is non-rival: since it can be consumed jointly by all consumers, society would like the producer to take into account the sum of all consumers' preferences.

7.2 Private Provision of Public Goods

We have now developed the conditions for the optimal provision of public goods: public goods should be produced until the marginal cost for producers equals the sum of the marginal rates of substitution for all consumers. With this finding in mind, the first question to ask (as always) is: Does the private sector get it right? If the private sector provides the optimal quantity of goods at the market price, then there is no market failure, and there is no potential role for the government in terms of improving efficiency.

Private-Sector Underprovision

free rider problem When an investment has a personal cost but a common benefit, individuals will underinvest.

In general, the private sector in fact *underprovides public goods* because of the **free rider problem** discussed in Chapter 5: since my enjoyment of public goods is not solely dependent on my contribution to them, I will contribute less to their provision than is socially optimal.

Let's consider this problem in the context of an example. Suppose Ben and Jerry live by themselves far away from others. It is July 4th, and they want to have a celebration. For this celebration, they care about only two consumption goods: ice cream cones and fireworks. The price of each of these goods is $1, so for every firework they buy, they forgo a serving of ice cream. Ice cream is a private good here, but fireworks are a pure public good: fireworks are non-rival since both Ben and Jerry can enjoy them without impinging on the other's enjoyment, and fireworks are non-excludable since they explode high in the sky for both Ben and Jerry to see. Neither Ben nor Jerry cares about who sends up the firework, as long as it's up in the sky for them to see. Both Ben and Jerry benefit equally from a firework sent up by either of them; what matters to them is the *total amount of fireworks*. To further simplify the example, suppose that Ben and Jerry have identical preferences over different combinations of fireworks and ice cream.

If left to their own devices, Ben and Jerry will choose to consume combinations of fireworks and ice cream cones identified by the points at which their indifference curves are tangent to their budget constraints. The slope of the budget constraints is 1, since fireworks and ice cream cones are each $1 per unit. The slope of the indifference curves is the *MRS*, or the ratio of marginal utilities. So both Ben and Jerry will set their marginal utility as $MU_F/MU_{ic} = 1$, or $MU_{ic} = MU_F$. This equivalence will determine the quantities of fireworks and ice cream cones consumed.

The optimality condition for public goods is that the marginal cost of the good should be set equal to the *sum* of marginal rates of substitution. Optimal consumption of fireworks would therefore occur at the point at which $MU^B_F/MU^B_{ic} + MU^J_F/MU^J_{ic} = 1$. Since Ben and Jerry's preferences are identical, this is equivalent to saying that $2 \times (MU_F / MU_{ic}) = 1$, or $MU_F = \frac{1}{2} \times MU_{ic}$.

Recall that marginal utilities diminish with increasing consumption of a good. In a private market equilibrium, fireworks are consumed until their marginal utility equals the marginal utility of ice cream (since the prices of both goods are $1). But the optimality calculation shows that fireworks should be consumed until their marginal utility is *half* the marginal utility of ice cream; that is, more fireworks are consumed in the optimal public goods outcome than in the private outcome.

This result is exactly what we would expect from the free rider problem. Ben and Jerry each have to forgo a serving of ice cream to provide a firework, but both Ben and Jerry benefit from each firework that is provided. There is a clear strong positive externality here: Ben's or Jerry's provision of the firework greatly benefits the other person. As we saw with positive externalities earlier, this situation leads naturally to underproduction. Thus, the free rider problem leads to a potential role for government intervention. (The appendix to this chapter works out a formal mathematical example of the free rider problem, illustrating how the private market underprovides the public good.)

APPLICATION

The Free Rider Problem in Practice[2]

The free rider problem is one of the most powerful concepts in all of economics, and it applies to everything from your everyday interactions to global politics. Some everyday examples, and interesting solutions, include the following:

- WNYC, the public radio station in New York, has an estimated listening audience of about 1 million people, but only 75,000 (7.5%) of their listeners send in money to support the station. Contributions account for only 35% of WNYC's budget. To avoid such a free rider problem in the United Kingdom, the national television station, the BBC, charges an annual licensing fee (currently around $200) to anyone who owns and operates a TV! The law is enforced by keeping a database of addresses recorded when TV purchases are made, and periodically a fleet of BBC vans scours the country with TV detection devices that can sense the "local oscillator" that operates when a TV is being used. If you're caught without a license, the fine can run up to $1,500.
- A 2000 study of the file-sharing software Gnutella showed that 70% of users download files only from others, and never contribute their own files via upload. The top 1% of Gnutella users contribute 40% of the total files shared, and the top 20% of users provide 98% of all files traded. The file-sharing software Kazaa now assigns users ratings based on their ratio of uploads to downloads and then gives download priority to users according to their ratings, thus discouraging free riders.
- In 1994, the town of Cambridge, England, tried to provide a public good in the form of 350 free green bicycles scattered throughout the city. Users were expected to return each bicycle to one of 15 stands after its use. Unfortunately, within four days of the scheme's launch, not a single bicycle could be found, most having been likely stolen and repainted a different color. The scheme ultimately cost the city about $20,000, thus posing the ultimate in literal "free rider" problems. ◄

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[2] Public radio data comes from Arik Hesseldahl's "Public Radio Goes Begging," a March 30, 2001, article in Forbes. The Gnutella study is described in Patti Hartigan's "Free Riders Who Don't Share in the Digital Community," an August 25, 2000, article for the *Boston Globe*. The British bicycle caper is reported in *The Times* (London) article of April 20, 1994, "Thieves Put Spoke in Freewheeling Dream."

Can Private Providers Overcome the Free Rider Problem?

The free rider problem does not lead to a complete absence of private provision of public goods. Many of us grew up in towns where there were privately financed fireworks displays, parks, even garbage collection. Indeed, one of the most famous counterarguments to the necessity of public provision of private goods was made for the case of lighthouses. Lighthouses seem to fit the definition of a pure public good: one ship's use of the light does not affect another's, and ships cannot be excluded from seeing the light when they are at sea. Indeed, for many generations, economists pointed to lighthouses as a classic example of a public good that would be underprovided by the private sector. John Stuart Mill was the first to argue that government should build lighthouses because "it is impossible that the ships at sea which are benefited by a lighthouse should be made to pay a toll on the occasion of its use." The great economist Paul Samuelson, in his classic text *Economics,* agreed that lighthouse building was "government activity justifiable because of external effects."[3]

Nonetheless, in a famous 1974 article, Ronald Coase (of Coase's theorem) conducted historical research showing that British lighthouses had been successfully provided by private interests long before the government ever took over the task. Private individuals, sensing a profitable opportunity, obtained permission from the government to build lighthouses and then levy tolls at the ports where the ships anchored. These individuals would determine how many lighthouses the ship had passed on its route and then charge them accordingly. Thus lighthouses were successfully provided by the private market until 1842, by which point the British government had purchased all private lighthouses in order to publicly provide this particular good.[4]

Thus, it appears that the private sector can in some cases combat the free rider problem to provide public goods. The previous example of file-sharing software shows one approach to doing so: charging user fees that are proportional to their valuation of the public good. The following policy application shows another example of privately financing public goods through such user fees—and the problems that such an approach can face.

APPLICATION

Business Improvement Districts

The quality of city streets is another example of a public good. Residents all want clean, safe spaces in which to walk, but it is infeasible to charge pedestrians a fee for using the streets. For this reason, cities use tax revenues to publicly

[3] These quotations come from Coase (1974), described next.

[4] According to Coase (1974), the reason put forth by the government was that government ownership would actually lower prices by preventing private owners from inflating prices. Coase then argues that the government takeover did not, in fact, lower prices.

provide police departments for safety, sanitation departments for cleanliness, and public works departments to decorate the public spaces. Unfortunately, public provision of these services does not always work effectively. Take, for example, New York City's Times Square, an area of midtown Manhattan that by 1980 was infested with muggers, pickpockets, heroin dealers, prostitutes, and stores selling pornography and various kinds of weapons. The city government spent ten years attempting to clean up Times Square, but eventually gave up on the area once described as "dirty, dangerous, decrepit and increasingly derelict."[5]

Then, in 1992, a group of local businessmen decided to start a Business Improvement District (BID), a legal entity that privately provides local security and sanitation services, and funds these services with fees charged to local businesses. In theory, BIDs should fail because of the free rider problem: each business will simply hope that other area businesses will pay for the services from which they all will benefit. The New York law, however, is structured so that if the BID organizers can get over 60% of the local business community to agree to join, then the BID can levy fees on all local businesses. In the Times Square case, 84% of local businesses agreed to pay fees in order to fund the BID's services.

The Times Square BID has been a resounding success. Now with a budget over $5 million, the BID has 120 employees, half of whom do sanitation duties like sweeping, emptying trash cans, and removing graffiti, while the other half work as unarmed "public safety officers" in conjunction with the police. Crime has dropped significantly, the area is cleaner and more attractive, and as a result of these improvements business and tourism are once again booming. As the head of the BID describes it, "What BIDs are able to do is to devote an intense effort to a small place that the city itself could never afford. It's a way of localizing much of the functions of government and concentrating your community effort." The BID's power to levy fees on local businesses allows seemingly public goods (safety and cleanliness) to be provided through private channels.

Whether a BID works well depends strongly on the form of the law allowing BIDs to form in the first place. In Massachusetts, for example, BID laws allow local businesses to opt out of paying the required fees within 30 days of approval of the BID by the local government. The opt-out approach discourages businesses from pursuing plans for BIDs because of a fear that, after all the groundwork for the plans has been laid, businesses will withdraw from the program at the last minute rather than pay their fee for BID costs. As a result of the provision, only 2 BIDs have successfully formed in Massachusetts; the rest of the nation has 1,500 scattered throughout the states.[6] ◄

[5] For more on the Times Square BID, see McDonald (2001).

[6] Kindleberger (1999).

When Is Private Provision Likely to Overcome the Free Rider Problem?

While the free rider problem clearly exists, there are also examples where the private market is able to overcome this problem to some extent. Under what circumstances are private market forces likely to solve the free rider problem, and under what circumstances are they not? In this section, we review three factors that are likely to determine the success of private provision: differences among individuals in their demand for the public good, altruism among potential donors to the public good, and utility from one's own contribution to the public good.

Some Individuals Care More than Others Private provision is particularly likely to surmount the free rider problem when individuals are not identical, and when some individuals have an especially high demand for the public good. For example, let's assume that Ben has more income than Jerry, but total income between the two is constant, so that the social optimum for fireworks is the same as when their incomes are equal. As we show mathematically in the appendix, in this case Ben would provide more fireworks than Jerry: if the income differential is large enough, the total number of privately provided fireworks rises toward the socially optimal number of fireworks. We obtain a similar outcome if Ben and Jerry have the same income, but Ben gets more enjoyment from fireworks; even though they are a public good, Ben will still provide more of them.

The key intuition here is that the decision about how many fireworks to provide for any individual is a function of the enjoyment that the individual gets from total fireworks, net of their cost. If a person gets a lot of enjoyment, or has a lot of money to finance the fireworks, he will choose to purchase more fireworks, even though he is sharing the benefits with others: as enjoyment net of costs gets very large for any one individual, the provision of the public good starts to approximate private good provision.

Consider, for example, a driveway that is shared by a mansion and by a run-down shack. In principle, there is a free rider problem in plowing the driveway, since the costs of plowing are borne by one party but both residences benefit from a clean driveway. Despite this, the mansion owner may nevertheless plow the driveway, allowing the owner of the shack to free ride, because the mansion owner has more money and perhaps cares more about having a clear driveway.

Higher incomes or stronger tastes for the public goods can mitigate the free rider problem to some extent, but they are not likely to solve the problem. Even when one individual provides all of a public good, the individual still does not take into account the benefit to other individuals, and so the public good is usually still underproduced (as in the appendix's example). Thus, while the owner of the mansion may end up plowing the driveway, he may not bother to plow as well near the shack as the shack's owner would like.

Altruism Another reason that private agents may provide more of a public good than our model would predict is that the model assumes purely selfish utility-maximizing agents. In fact, there is much evidence that individuals are

altruistic When individuals value the benefits and costs to others in making their consumption choices.

altruistic—that is, they care about the outcomes of others as well as themselves. If individuals are altruistic, they may be willing to contribute to a public good even if the free rider problem suggests they should not. In terms of our model, this would be equivalent to Ben caring not only about the costs of fireworks to himself, but the cost to Jerry as well, so that he is willing to contribute more in order to lower Jerry's burden.

Evidence for altruism comes from *laboratory experiments* of the kind that are typically employed in other fields, such as psychology, but that are gaining popularity as a means of resolving difficult economic issues. The typical public goods experiment proceeds as follows: five college undergraduates are placed in a room to play ten rounds of a simple game. In each round, the students are given \$1, and they have the option of keeping that \$1 or placing it in a "public" fund. After all students decide whether to contribute, the amount in the public fund is then doubled (by the economist running the experiment) and divided up evenly among all five students, *regardless of whether or not they contributed.* Thus, if all choose to contribute \$1 to the fund, they each receive \$2 in return. If only 2 contribute to the fund, each of the contributors receives \$0.40 (2 × \$2/5 students), while the noncontributors retain their full \$1 *and* get the \$0.40 from the public fund, for a total of \$1.40. In this case, the contributors lose money and the noncontributors make money. There is thus a very clear incentive to free ride off the contributions of others, so that economists predict theoretically that no one should ever contribute to the public fund. If we start from a point of no contributors, any particular individual loses money by voluntarily becoming a contributor, so no one should do so.

The experimental evidence shows an outcome that is very different from that predicted by economic theory. As reviewed in Ledyard (1995), nearly every such public goods experiment results in 30–70% of the participants contributing to the public fund. Interestingly, in experiments with multiple rounds, such as the one just described, contributions tend to decline as the rounds progress, but rarely, if ever, reach zero. Thus, altruism appears to trump the purely selfish prediction that underlies the theory of the free rider problem.

Laboratory experiments, however, suffer from some limitations as a source of information about real-world behavior. Individuals may behave differently in a laboratory setting, where the stakes are often small, than they do in actual markets, where the stakes can be higher. Moreover, most of the experimental evidence used in economics comes from laboratory work with college undergraduates, which may not provide a representative answer for the entire population of interest.

Nevertheless, some real-world evidence is also consistent with altruism in private support of public goods. For example, Brunner (1998) noted that the traditional theory of public goods suggests that as the numbers of users of a good increases, the tendency for individuals to contribute to the financing of that good should decrease as they feel that their contribution has less and less of an impact (with only one user, there is no free rider possibility, but as the number of users grows, each individual's contribution benefits that person less and less and others more and more). Brunner therefore studied public radio stations across the country, examining listeners' contributions in relation to the total size of a given station's audience. Surprisingly, Brunner found that the number of listeners contributing decreases only modestly as the number of listeners increases, and that, among contributors, the amount of the contribution is unchanged. This seems to suggest that there is a subset of public goods contributors who get utility simply out of giving what they feel is their appropriate share.

social capital The value of altruistic and communal behavior in society.

What determines altruism? This is a very difficult question and has given rise to an entire field of study of **social capital,** the value of altruistic and communal behavior in society. A central finding of this field is that individuals are likely to be more altruistic when they are more "trusting" of others. For example, Anderson et al. (2003) ran a typical public goods experiment of the type described, and paired the results across individuals with both attitudinal measures of trust (do you agree with statements like "most people can be trusted"?) and behavioral measures of trust (do you loan money to friends and strangers? have you ever been a crime victim? do you purposefully leave your doors unlocked? and so on). They found that most of the attitudinal and behavioral measures of trust were positively correlated with high contributions to the public good. In the Bangladeshi trash collection example that opened this chapter, the few communities that were successful in setting up private trash collection were those neighborhoods that tended to exhibit higher levels of "reciprocity" (do you help neighbors after a householder dies? do you and your neighbors help take each other for visits to the hospital or doctor?) and "sharing" (do you send your neighbors food during festivals or other happy occasions? do you and your neighbors share fruits/vegetables grown on your own premises?).

warm glow model Model of public goods provision in which individuals care about both the total amount of the public good and their particular contributions as well.

Warm Glow A final reason that private individuals might provide more of the public good than suggested by our model is that individuals might care about their own contributions per se. Under the **warm glow model,** individuals care about both the total amount of the public good and their particular contributions as well. Perhaps they get a plaque with their name on it from making contributions, or maybe their contributions are known publicly so that their friends praise them for their generosity, or maybe they get a psychological benefit from knowing they helped a worthy cause. If individuals get utility from their particular contributions for any reason, the public good becomes like a private good, and individuals will contribute more than predicted by our original model (in which they care only about the total public good quantity). Warm glow does not fully solve the underprovision problem, however, since individuals still do not account for the positive benefits to others of their public goods provision.

7.3 Public Provision of Public Goods

The discussion in Section 7.2 highlights that the private sector will generally underprovide public goods, so that government can potentially improve efficiency by intervening. In principle, the government could solve the optimal public goods provision problem previously presented and then either provide that amount of the good or mandate private actors to provide that amount.

In practice, however, governments face some significant barriers when they attempt to solve the free rider problem in the provision of public goods. In this section, we review three of those barriers: private responses to public provision, or "crowd-out"; the difficulty of measuring the costs and benefits of public goods; and the difficulty of determining the public's preferences for public goods.

Private Responses to Public Provision: The Problem of Crowd-Out

In some instances, public goods will not be provided at all by those in the private sector unless the government tells them they must provide the good. In other cases, as we noted, the private sector is already providing the public good to some extent before the government intervenes, and this private provision will react to government intervention. In particular, public provision will to some extent **crowd out** private provision: as the government provides more of the public good, the private sector will provide less. This decrease in private provision will offset the net gain in public provision from government intervention.

crowd-out As the government provides more of a public good, the private sector will provide less.

The extent of such crowd-out depends on the preferences of the private individuals providing the public good. Let's continue to explore the fireworks example and make three assumptions:

1. Ben and Jerry care only about the total amount of fireworks provided: there is no warm glow from giving.
2. The government provision of fireworks will be financed by charging Ben and Jerry equal amounts.
3. The government provides fewer fireworks than Ben and Jerry were providing beforehand.

In this case, as we show mathematically in the appendix, *each dollar of public provision will crowd out private provision one for one*. That is, the government's intervention will have no *net effect* on the quantity of fireworks provided.

This outcome illustrates the fundamental *robustness of economic equilibria:* if a person starts from his or her individual optimum, and the market environment changes, and if the person can undo this change to get back to that optimum, he or she will do so. The private equilibrium is the preferred outcome for Ben and Jerry. If they can undo any government intervention to get back to that preferred outcome, they will do so; what was optimal before the government intervened remains optimal after government intervention given our three earlier assumptions.

For example, suppose that in the pregovernment optimum, Ben and Jerry were each providing 10 fireworks, at a cost of $10 for each person. The total private provision is therefore 20 fireworks, but let's say the social optimum is 30 fireworks. To reach the social optimum, the government decides to take $5 each from Ben and from Jerry, and use the $10 raised to buy 10 more fireworks. Ben and Jerry each have $5 less, and they observe the government providing 10 fireworks. They simply cut their spending on fireworks by $5 each, so that they spend the same ($5 on fireworks, $5 to the government), and see the same total fireworks (20). So they are exactly where they originally wanted to be, and the government intervention has done nothing. This is a case of full crowd-out.

Crowd-out is a classic example of the unintended consequences of government action that we first discussed in Chapter 1. The government intended to do the right thing by increasing fireworks to the social optimum. But, in fact, it ended up having no effect, because its actions were totally offset by changes in individual actions.

Full crowd-out is rare. Partial crowd-out is much more common and it can occur in two different cases: when noncontributors to the public good are taxed to finance provision of the good, and when individuals derive utility from their own contribution as well as from the total amount of public good.

Contributors vs. Noncontributors Suppose that some people contribute more for public goods than others, either because they are richer or because they have a stronger preference for the public good. In the extreme case, suppose that Ben contributes $20 to buy 20 fireworks, and Jerry contributes nothing, because Ben likes fireworks more than Jerry or because he is richer than Jerry. This is still below the social optimum of 30 fireworks, however.

Now, suppose that the government charges Ben and Jerry each $5 for firework contributions and then provides 10 fireworks in an attempt to bring the number of fireworks to the socially optimal level of 30. Jerry now spends $5 more on fireworks, since he was providing nothing before. Ben, on the other hand, will not reduce his firework consumption by the full $10 (to offset government provision). Ben has effectively been made better off: there are 10 more fireworks that only cost him $5 in government-mandated contributions, rather than the $10 he would have spent if he'd bought those 10 fireworks. This increase in Ben's effective wealth (the value of fireworks plus the value of other goods he can purchase) has a positive income effect on Ben's purchase of fireworks, so government intervention will not fully crowd out his spending. The total number of fireworks will rise above 20. By forcing Jerry to become a contributor, the government has increased total public goods provision.

Warm Glow Alternatively, there may not be full crowd-out if I care about my own contributions per se, as in the warm glow model. If I get utility from my particular contributions for any reason, then an increase in government contributions will not fully crowd out my giving. For example, consider the extreme case where *all* I care about is how much I give, and I don't care about gifts from others. If the government increases contributions from others, these contributions have no offsetting effects on my giving because my giving is, from my perspective, a private good. In this extreme case, there may be *no* crowd-out of my contributions by government intervention. As long as there is some warm glow from my own contributions, then crowd-out will be less than one for one, since part of my contribution is a private good.

Evidence on Crowd-Out How important a problem is crowd-out in reality? Unfortunately, the existing evidence on crowd-out is quite mixed. On the one hand, studies assessing how individual contributions respond to government spending suggest very small crowd-out. As the Empirical Evidence box reviews, however, these studies suffer from many of the bias problems discussed in Chapter 3. On the other hand, evidence from laboratory experiments suggest that crowd-out is large, but less than full. Thus, while there is no evidence for full crowd-out, there is also no consensus on the size of this important individual response to government intervention.

Measuring the Costs and Benefits of Public Goods

In the previous theoretical analysis, we assumed that the government could measure both the benefits and costs of providing public goods. In practice, this is quite difficult. Consider the example of improving a highway in order to reduce traffic slowdowns and improve safety. There is a clear free rider problem in relying on the private sector for this improvement. The benefits of highway improvement are fairly small for any one driver, although they may be quite large for the total set of drivers using the highway. Thus, no one driver will invest the necessary resources to improve the highway.

Should the government undertake these highway improvements? That depends on whether the costs of doing so exceed the sum of the benefits to all drivers who use the highway, but measuring these costs and benefits can be complicated. Consider the costs of the labor needed to repair the highway. The budgetary cost of this labor is the wage payments made by the government for this labor, but the economic costs can be different. What if, without this highway project, half of the workers on the project would be unemployed? How can the government take into account that it is not only paying wages but also providing a new job opportunity for these workers?

There are even more difficult problems facing the government as it tries to assess the benefits of the project. What is the value of the time saved for commuters due to reduced traffic jams? And what is the value to society of the reduced number of deaths if the highway is improved?

These difficult questions are addressed by the field of *cost-benefit analysis,* which provides a framework for measuring the costs and benefits of public projects. Chapter 8 provides a detailed discussion of cost-benefit analysis, within the context of this highway example.

How Can We Measure Preferences for the Public Good?

In our discussion of optimal public goods provision, the government knows each individual's preferences over private and public goods. The government can therefore compute for each individual that person's marginal valuation of public goods (his or her marginal rate of substitution of the public for the private good), sum these valuations across all individuals, and set this equal to the marginal cost of the public good (relative to the marginal cost of the private good).

EMPIRICAL EVIDENCE

MEASURING CROWD-OUT

There are a large number of studies that consider how private spending on public goods responds to public spending on the same public goods. A classic example is Kingma's (1989) study of public radio. Public radio is supported partly by contributions from its listeners and partly by government contributions. Kingma collected data on how much governments contribute to public radio stations in different cities around the country. He then gathered data on how much individuals contribute to their public radio stations in those same cities. He found that for every $1 increase in government funding, private contributions fell by 13.5¢, for only a very partial crowd-out. Other studies in this vein typically also find that crowd-out is fairly small.[7]

This is an interesting finding, but it potentially suffers from the bias problems discussed in Chapter 3: there may be reasons why areas with different government contributions to public radio might also have different tastes for private giving. For example, suppose that governments are more able to support public radio in high-income areas than in low-income areas (since the government raises more tax revenues in the high-income areas), and that individuals contribute more to charitable causes (like public radio) in high-income areas than in low-income areas. Then high-income and low-income areas are not good treatment and control groups to use for measuring the effect of government spending on individual giving. Such comparisons will be biased by the fact that high-income areas would have given more even in the absence of government intervention. In principle, regression analysis using controls for income can correct this bias, but in practice, as discussed in Chapter 3, controls are typically unable to fully correct this type of problem.

The other type of evidence that has been used in this area comes from laboratory experiments. The classic study using this approach is Andreoni (1993). He set up an experiment in which individuals contributed to a public good in a laboratory setting by contributing tokens they were given to a common fund. He set up the payoffs for this experiment so that each player, if acting as a free rider, should choose to contribute 3 tokens in order to maximize the player's likely return. This predicted contribution (3 tokens) was close to the level actually chosen by each participant (2.78 tokens).[8]

Andreoni then made the following change to the laboratory game: using the same payment schedule, he instituted a 2-token tax on every player. This tax was then contributed to the public good. This change mirrors the full earlier crowd-out example, so without warm glow effects, players should have reduced their contributions by 2 tokens to 0.78 tokens to offset the government contribution plan. In fact, however, each player cut his or her contributions by only 1.43 tokens, so that contributions fell only to 1.35 tokens. That is, crowd-out was less than full; each token of government contribution crowded out only 0.715 tokens of private contributions.

This crowd-out estimate is much higher than that obtained from empirical studies: recall that Kingma's estimate was that a dollar of government contribution would crowd out only 0.135 dollars of private contributions. At the same time, as already noted, laboratory experiments have their limitations as a source of economic evidence. Thus, the true extent of crowd-out remains an important question.

In practice, of course, there are at least three problems facing a government trying to turn individual preferences into a decision about public goods provision. The first is *preference revelation:* individuals may not be willing to tell the government their true valuation, for example, because the government might

[7] See Steinberg (1991) or Straub (2003) for reviews; Straub even finds that the small Kingma crowd-out is not significant when using an updated and larger sample.

[8] Andreoni's subjects did behave very much like free riders, unlike the altruistic cases discussed earlier, perhaps because they were economics students who were given time to study the structure of the game. In one public goods experiment, Marwell and Ames (1981) showed that graduate students in economics free ride much more than the general population, contributing only 20% of their tokens compared to 49% for the other subjects.

charge them more for the good if they say that they value it highly. The second is *preference knowledge:* even if individuals are willing to be honest about their valuation of a public good, they may not know what their valuation is, since they have little experience pricing public goods such as highways or national defense. The third is *preference aggregation:* how can the government effectively put together the preferences of millions of citizens in order to decide on the value of a public project?

These difficult problems are addressed by the field of *political economy,* the study of how governments go about making public policy decisions such as the appropriate level of public goods. In Chapter 9, we'll discuss the various approaches used by governments to address these problems, and their implications for the ability of governments to effectively intervene in problems such as the free rider problem.

7.4 Conclusion

A major function of governments at all levels is the provision of public goods. The potential gains from such government intervention are apparent from free rider problems, such as those impeding garbage collection in Bangladesh. In some cases, the private sector can provide public goods, but in general it will not achieve the optimal level of provision.

When there are problems with private market provision of public goods, government intervention can potentially increase efficiency. Whether that potential will be achieved is a function of both the ability of the government to appropriately measure the costs and benefits of public projects and the ability of the government to carry out the socially efficient decision. In the next two chapters, we investigate those two concerns in detail.

▶ HIGHLIGHTS

- Pure public goods are goods that are non-rival (my consuming or making use of the good does not in any way affect your opportunity to consume the good) and non-excludable (even if I want to deny you the opportunity to consume or access the public good, there is no way I can do so).
- For pure public goods, the optimal level of provision is the point at which the sum of marginal benefits across all recipients equals the marginal cost.
- The private market is unlikely to provide the optimal level of public goods due to the free rider problem.
- In some cases, the private market can overcome the free rider problem, at least partially. A solution closer to the socially optimal one is more likely if there are individuals with high incomes or high demand for the public good, individuals who are altruistic, or individuals who derive a "warm glow" from their contributions.
- Public provision of public goods faces three important problems: crowding out of private provision; determining the costs and benefits of public projects; and effectively reflecting the public's demand for public goods.

▶ QUESTIONS AND PROBLEMS

1. We add the demands of *private* goods horizontally but add the demands of *public* goods vertically when determining the associated marginal benefit to society. Why do we do this and why are the procedures different for public and private goods?

2. The citizens of Balaland used to pave 120 miles of roadways per year. After the government of Balaland began paving 100 miles of roadways per year itself, the citizens cut back their paving to 30 miles per year, for a total number of roadway miles paved per year of only 130 miles. What might be happening here?

3. Bill's demand for hamburgers (a private good) is $Q = 20 - 2P$ and Ted's demand is $Q = 10 - P$.
   a. Write down an equation for the social marginal benefit of the consumption of hamburger consumption.
   b. Now suppose that hamburgers are a *public* good. Write down an equation for the social marginal benefit of hamburger consumption.

4. People in my neighborhood pay annual dues to a neighborhood association. This association refunds neighborhood dues to selected home owners who do a particularly nice job in beautifying their yards.
   a. Why might the neighborhood association provide this refund?
   b. At the most recent home owners' association meeting, home owners voted to end this practice because they felt that it was unfair that some people would not have to pay their share of the costs of maintaining the neighborhood. What is likely to happen to the overall level of neighborhood beautification? Explain.

5. Zorroland has a large number of people who are alike in every way. Boppoland has the same number of people as Zorroland, with the same average income as Zorroland, but the distribution of incomes is wider. Why might Boppoland have a higher level of public good provision than Zorroland?

6. Think about the rival and excludable properties of public goods. To what degree is *radio broadcasting* a public good? To what degree is a *highway* a public good?

7. Think of an example of a free rider problem in your hometown. Can you think of a way for your local government to overcome this problem?

8. In order to determine the right amount of public good to provide, the government of West Essex decides to survey its residents about how much they value the good. It will then finance the public good provision by taxes on residents. Describe a tax system that would lead residents to underreport their valuations. Describe an alternative system that could lead residents to overreport their valuations.

9. Why is it difficult to empirically determine the degree to which government spending crowds out private provision of public goods?

10. Think back to Chapter 5. Why can the public good provision problem be thought of as an externality problem?

▶ ADVANCED QUESTIONS

11. Suppose ten people each have the demand $Q = 20 - 4P$ for streetlights, and 5 people have the demand $Q = 18 - 2P$ for streetlights. The cost of building each streetlight is 3. If it is impossible to purchase a fractional number of streetlights, how many streetlights are socially optimal?

12. Andrew, Beth, and Cathy live in Lindhville. Andrew's demand for bike paths, a public good, is given by $Q = 12 - 2P$. Beth's demand is $Q = 18 - P$, and Cathy's is $Q = 8 - P/3$. The marginal cost of building a bike path is $MC = 21$. The town government decides to use the following procedure

for deciding how many paths to build. It asks each resident how many paths they want, and it builds the largest number asked for by any resident. To pay for these paths, it then taxes Andrew, Beth, and Cathy the prices a, b, and c per path, respectively, where $a + b + c = MC$. (The residents know these tax rates before stating how many paths they want.)

a. If the taxes are set so that each resident shares the cost evenly ($a = b = c$), how many paths will get built?

b. Show that the government can achieve the social optimum by setting the correct tax prices a, b, and c. What prices should it set?

13. The town of Springfield has two residents: Homer and Bart. The town currently funds its fire department solely from the individual contributions of these residents. Each of the two residents has a utility function over private goods (X) and total firefighters (M), of the form $U = 4 \times \log(X) + 2 \times \log(M)$. The total provision of firefighters hired, M, is the sum of the number hired by each of the two persons: $M = M_H + M_B$. Homer and Bart both have income of \$100, and the price of both the private good and a firefighter is \$1. Thus, they are limited to providing between 0 and 100 firefighters.

a. How many firefighters are hired if the government does not intervene? How many are paid for by Homer? By Bart?

b. What is the socially optimal number of firefighters? If your answer differs from (a), why?

14. The town of Musicville has two residents: Bach and Mozart. The town currently funds its free outdoor concert series solely from the individual contributions of these residents. Each of the two residents has a utility function over private goods (X) and total concerts (C), of the form $U = 3 \times \log(X) + \log(C)$. The total number of concerts given, C, is the sum of the number paid for by each of the two persons: $C = C_B + C_M$. Bach and Mozart both have income of 70, and the price of both the private good and a concert is 1. Thus, they are limited to providing between 0 and 70 concerts.

a. How many concerts are given if the government does not intervene?

b. Suppose the government is not happy with the private equilibrium and decides to provide 10 concerts in addition to what Bach and Mozart may choose to provide on their own. It taxes Bach and Mozart equally to pay for the new concerts. What is the new total number of concerts? How does your answer compare to (a)? Have we achieved the social optimum? Why or why not?

c. Suppose that instead an anonymous benefactor pays for 10 concerts. What is the new total number of concerts? Is this the same level of provision as in (b)? Why or why not?

15. Consider an economy with three types of individuals, differing only with respect to their preferences for monuments. Individuals of the first type get a fixed benefit of 100 from the mere existence of monuments, whatever their number. Individuals of the second and third type get benefits according to:

$$B_{II} = 200 + 30M - 1.5M^2$$
$$B_{III} = 150 + 90M - 4.5M^2$$

where M denotes the number of monuments in the city. Assume that there are 50 people of each type. Monuments cost \$3,600 each to build. How many monuments should be built?

The **C** icon indicates a question that requires students to apply the empirical economics principles discussed in Chapter 3 and the Empirical Evidence boxes.

Appendix to Chapter 7

The Mathematics of Public Goods Provision

In this appendix, we present the mathematics behind the analysis of the private provision of public goods and discuss how government intervention affects that provision. This analysis uses the tools of *game theory,* a method used by economists to solve problems in which multiple parties interact to make a decision.

Setup of the Example

Imagine that Ben and Jerry live by themselves far away from others. They choose between consuming a private good, X, with a price of \$1 ($P_x = 1$), and a public good, fireworks, with a price of \$1 ($P_F = 1$). They each have income of \$100. Because fireworks are a public good, the total amount provided is the sum of the amount provided by each individual: $F = F_B + F_J$. Each individual (i) has a utility function of the form:

$$U = 2 \times \log(X_i) + \log(F_B + F_J)$$

which he maximizes subject to the budget constraint

$$X_i + F_i = 100$$

Private Provision Only

Initially, Ben and Jerry provide the public good on their own, with no government intervention. A question for modeling private provision is how Ben and Jerry will behave, given that each knows the other will also provide fireworks. Game theory models designed to answer questions such as these typically assume *Nash bargaining:* each actor solves for his or her optimal strategy given the other actor's behavior, and an equilibrium exists if there is a set of mutually compatible optimal strategies. The *Nash equilibrium* is the point at which each actor is pursuing his or her optimal strategy, given the other actor's behavior.

Combining the equations for the utility function and the budget constraint, Ben solves a problem of the form:

$$\text{Max } U = 2 \times \log(100 - F_B) + \log(F_B + F_J)$$

Differentiating this expression with respect to F_B, we obtain:

$$-2/(100 - F_B) + 1/(F_B + F_J) = 0$$

which we can solve to generate:

$$(100 - F_B)/(2 \times (F_B + F_J)) = 1$$

and therefore

$$F_B = (100 - 2F_J)/3$$

Note the free rider problem implied by this equation: Ben's contribution goes down as Jerry's contribution goes up.

We can solve a similar problem for Jerry:

$$F_J = (100 - 2F_B)/3$$

This yields two equations in two unknowns, which we can combine to solve for F_B and F_J. Doing so, we find that $F_B = F_J = 20$, so the total supply of fireworks is 40.

Socially Optimal Level

How does this compare to the socially optimal level of provision? The social optimum is the quantity at which the sum of the individuals' marginal rates of substitution equals the ratio of prices (which is 1 in this example). Each individual's *MRS* is the ratio of his marginal utility of fireworks to his marginal utility of private goods, which we obtain by differentiating the previous utility function with respect to fireworks and then again with respect to private goods. So the optimal amount of fireworks is determined by:

$$(100 - F_B)/[2 \times (F_B + F_J)] + (100 - F_J)/[2 \times (F_B + F_J)] = 1$$

Using the fact that total fireworks $F = F_B + F_J$, we can rewrite this equation as:

$$(200 - F)/2F = 1$$

Solving this, we obtain $F = 66.6$. This quantity is much higher than the total provision by the private market, 40, due to the free rider problem. The public good is underprovided by the private market.

Different Types of Individuals

Suppose now that Ben has an income of 125, while Jerry has an income of only 75. In that case, Ben maximizes:

$$U = 2 \times \log(125 - F_B) + \log(F_B + F_J)$$

So Ben's demand for fireworks is:

$$F_B = (125 - 2F_J)/3$$

Jerry, in this case, maximizes his utility:

$$U = 2 \times \log(75 - F_J) + \log(F_B + F_J)$$

So Jerry's demand for fireworks is:

$$F_J = (75 - 2F_B)/3$$

Solving these two equations, we find that $F_B = 45$ and $F_J = -5$. Since individuals can't provide negative fireworks, this means that Jerry provides no fireworks, and the total supply is 45. This quantity is higher than the private quantity supplied when Ben and Jerry have equal incomes. Thus, having one actor with a higher income leads the outcome to be closer to the social optimum.

Full Crowd-Out

Suppose the government recognizes that the private sector underprovides fireworks by a total of 26.6 in the original example. It therefore attempts to solve this problem by mandating that Ben and Jerry each contribute \$13.30 toward more fireworks. Will this solve the underprovision problem?

In fact, it will not; such a mandate will simply crowd out existing contributions. Under the mandate, Both Ben and Jerry now maximize their utility, which has the form:

$$Max\ U = 2 \times \log(X_i) + \log(F_B + F_J + 26.6)$$

Each maximizes that utility function subject to the budget constraint:

$$X_i + F_i = 100 - 13.3$$

Solving this problem as above, we find that the optimal level of fireworks provision for both Ben and Jerry falls to 6.7 each, so that total provision (public of 26.6 plus private of 13.4) remains at 40. By reducing their provision to 6.7, Ben and Jerry can return to the private solution that they find to be optimal, which is total spending of \$20 each, and a total of 40 fireworks. As discussed in the chapter, however, full crowd-out is only one of a range of possible outcomes when government provides a good that is also provided by the private sector.