CHAPTER 5

Externalities: Problems and Solutions

Questions to keep in mind

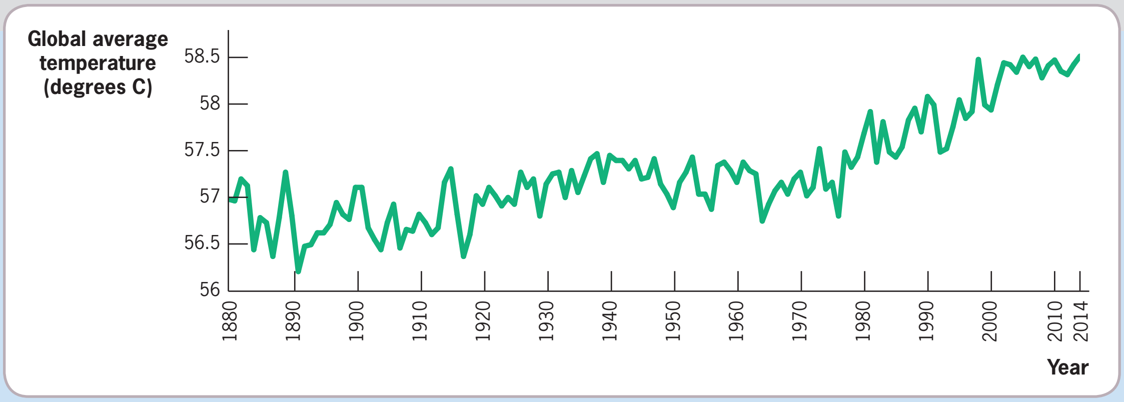
- What is an externality, and why does it cause a market failure?
- When can the private market solve the problem of externalities?
- What are possible public-sector solutions to the problem of externalities, and what are the advantages and disadvantages of each?

In December 1997, representatives from more than 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 shows, there has been a steady rise in global temperatures in the twentieth and twenty-first centuries. 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 11.5 degrees Fahrenheit.[1]

If you are reading this in North Dakota, that may sound like good news. Indeed, for some of the United States, this increase in temperatures is likely to 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

[1] International Panel on Climate Change (2007). 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."

FIGURE 5-1



Average Global Temperature, 1880–2014 • There was a steady upward trend in global temperature throughout the twentieth century, which has continued into the twenty-first century.

Data from: Figure adapted from NASA's Goddard Institute for Space Studies, "Global Annual Mean Surface Air Temperature Change" (2015), located at http://data.giss.nasa.gov/gistemp/graphs_v3/.

feet, increasing risks of flooding and submersion of low-lying coastal areas. Some scientists project, for example, that 20 to 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 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 (pre-industrial) levels. Yet, even to reduce fossil fuel use to the level ultimately mandated by this Kyoto conference (7% below 1990 levels) would have cost the United States $1.6 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.

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.

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 Bangladesh will be flooded out of existence in 100 years. 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.

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[2] Mirza et al. (2003).

[3] This is the total cost over future years of reducing emissions, not a one-year cost. Nordhaus and Boyer (2000), Table 8.6 (updated to 2014 GDP).

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 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. But due to government regulations that we discuss in Chapter 6, there has been an enormous reduction in this type of pollution.

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 show in this chapter, externalities present a classic justification for government intervention. Indeed, 176,950 federal employees, or about 6.4% of the federal workforce, are ostensibly charged with dealing with environmental externalities in agencies such as the Environmental Protection Agency (EPA) and the Department of the Interior.[4]

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

This chapter begins with a discussion of the nature of externalities. Throughout the chapter, we focus primarily 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 earlier) 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

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[4] Estimates from U.S. Office of Personnel Management (2012).

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 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 because 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.

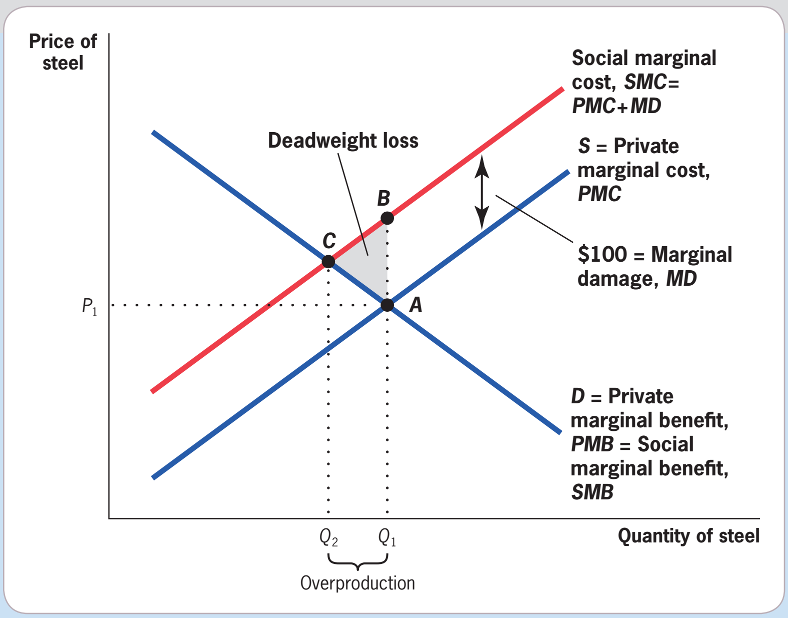
One way to see this externality is to graph the market for the steel produced by this plant (Figure 5-2) and compare the private benefits and costs of production to the social benefits and costs. Private benefits and costs are the benefits and costs borne directly by the actors in the steel market (the 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).

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.

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

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*.

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, the social costs of producing steel are equal to the costs to steel producers, $SMC = PMC$. 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 because 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 minus 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. Because 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

[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. The height of the triangle is the difference between the marginal social cost and the marginal social benefit, the marginal damage.

(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 ($Q_1 - Q_2$).

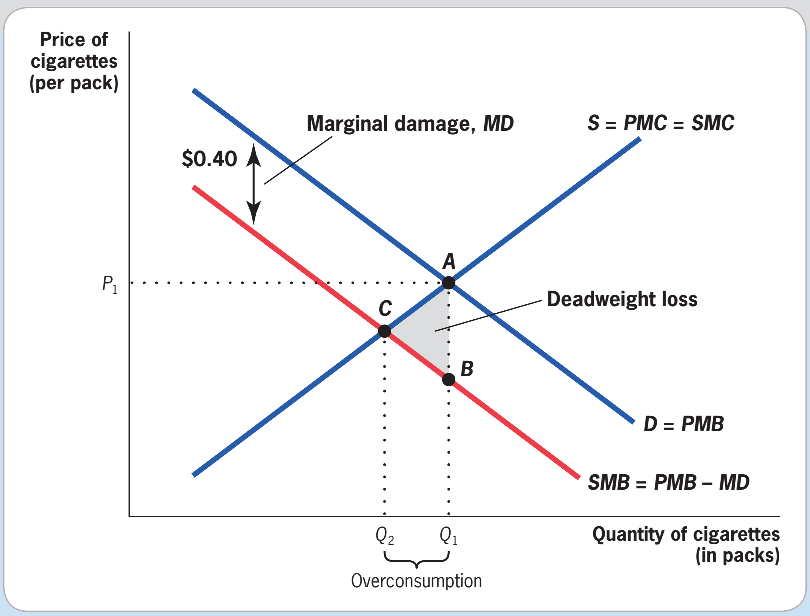
Negative Consumption Externalities

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

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 **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.

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

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*.

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 because each pack consumed imposes 40¢ of costs on others for which they are not compensated.

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. In 2013, the typical driver is in a car that weighed about 4,015 pounds, 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 4,742 pounds, represented only 6.4% of vehicle sales as recently as 1988, but 26 years later, in 2014, they accounted for 52% of the new vehicles sold that year.[7]

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 27.6 miles to the gallon, but the typical SUV gets only 21.7 miles per 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 In 2014, federal, state, and local governments in the United States spent $165 billion repairing our roadways. 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) because the SUV uses more gas, but it is unclear if these extra taxes are enough to compensate for the extra damage done to roads.

ROBERT DODGE/E+/GETTY IMAGES

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[6] All data in this application are from the U.S. Environmental Protection Agency (2015), the U.S. Department of Transportation Federal Highway Administration (2014), Steele (2015), and the Congressional Budget Office (2014).

[7] Steele (2015).

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

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

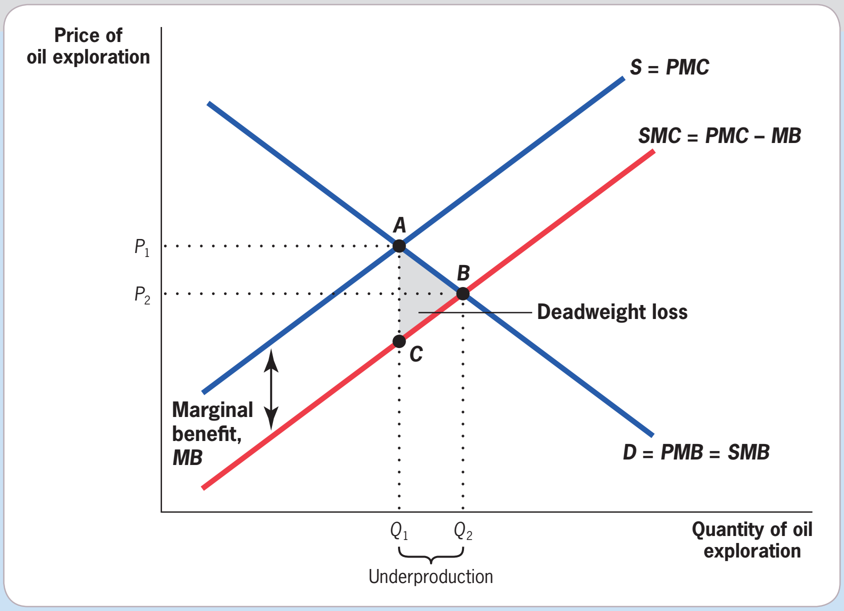
When economists think about externalities, they tend to focus on negative externalities, but not all externalities are bad. There may also be **positive production externalities** associated with a market, whereby production benefits parties other than the producer and yet the producer is not compensated. 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, so 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.

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 socially optimal level (point *B*, quantity Q_2) because the initial oil company is not compensated for the benefits it confers on other oil producers.[8] 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

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

[8] The presence of positive production externalities is of long-standing interest to economists. Recently, Greenstone et al. (2010) suggests that there may be "agglomeration economies," whereby large new plants raise the productivity of surrounding plants through creating richer labor markets, lowering transportation costs between buyer and seller, or fomenting conditions for easy knowledge transfer. They compare counties that "win" contests for major new plans to those that "lose" and find that the winners have much faster productivity growth for existing plants in the area.

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*.

benefit to my neighbor is only $800. Because 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, because his private 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?[9]

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: he would pay the fishermen $100 for each unit of steel produced, so that they were fully compensated for the damage to their fishing grounds. So 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.

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

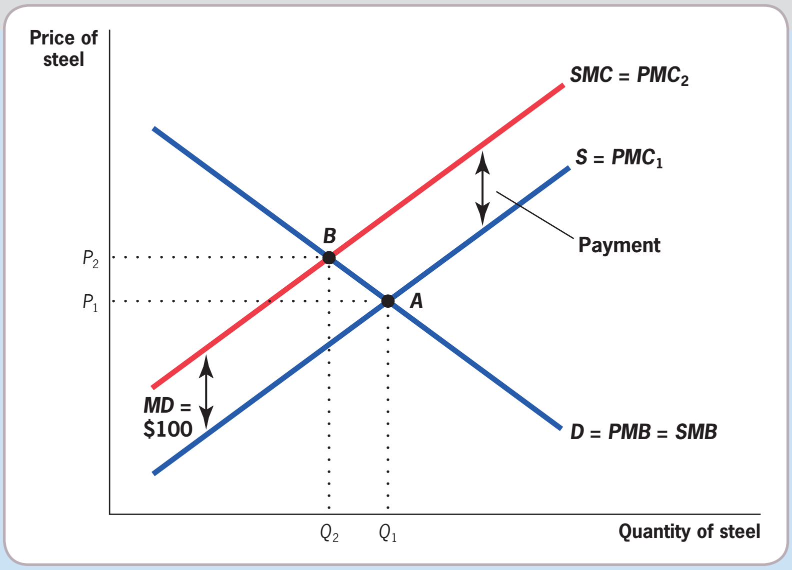
This type of resolution is called **internalizing the externality.** Because the fishermen now have property rights to the river, they have used the market to obtain compensation from the steel plant for its pollution. The fishermen have implicitly created a market for pollution by pricing the bad behavior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

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 illustrates **Part I of the Coase Theorem:** when there are well-defined property rights and costless bargaining, then negotiations between the party creating the

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.

[9] 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.

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, so 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.

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

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 that 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 because 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?

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 owner 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.

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

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 because 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 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.[10]

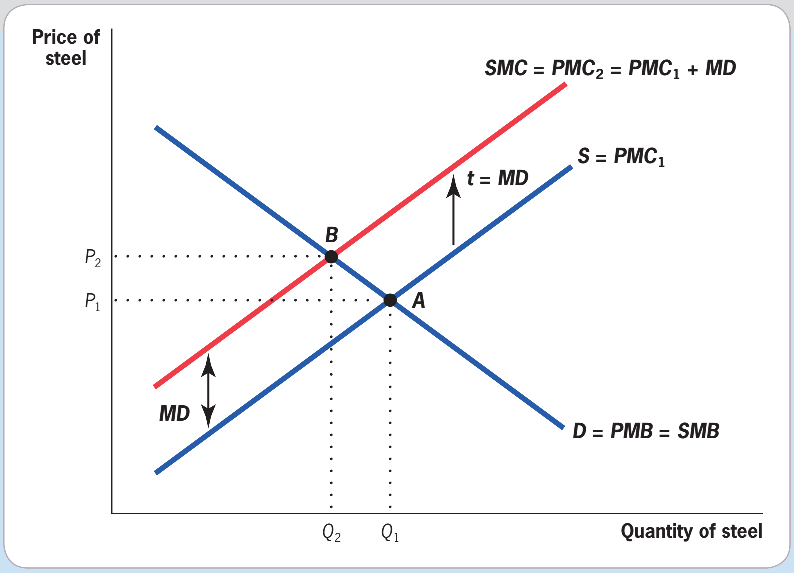
Public policy makers employ three types of remedies to resolve the problems associated with negative externalities.

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 the marginal damage of the pollution) for each unit of steel produced.

[10] Visit www.epa.gov for more information.

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.

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.[11]

Subsidies

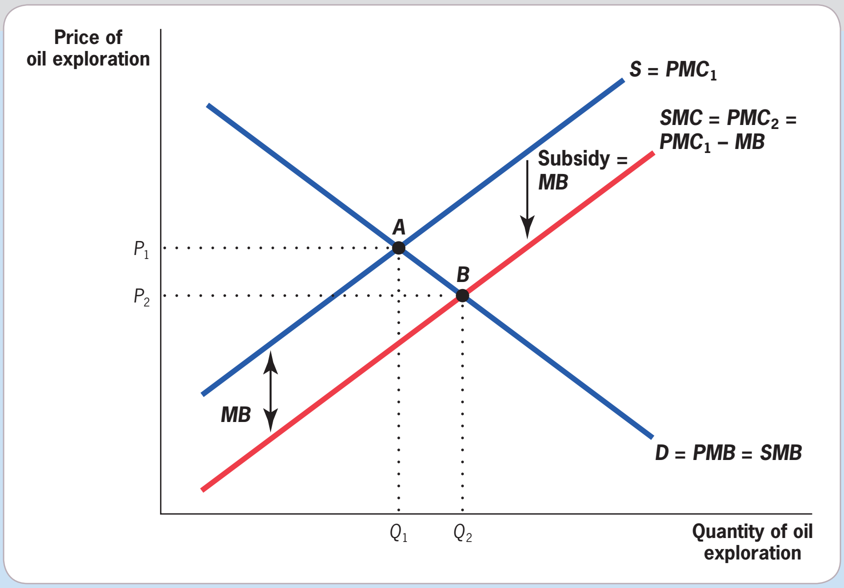
As noted earlier, not all externalities are negative; in cases such as oil exploration or nice landscaping by your neighbors, externalities can be positive.

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,**

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

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

FIGURE 5-7



Subsidies as a Solution to Positive Production Externalities in the Market for Oil Exploration • A subsidy that equals 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.

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 because his cost per barrel has been lowered.

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.

Policy makers often use subsidization not just to promote positive externalities but to combat negative externalities as well, by subsidizing alternatives to the externality-producing activity. The most common form of such policies are tax credits or other benefits for producers of renewable energies (such as solar or wind power) that produce fewer environmental externalities than traditional energy sources (such as fossil fuels). Such policies are generally inferior to taxing the negative externality–producing activity because they require government to raise revenues rather than provide revenues (as we show in Chapters 18–20, as you raise the government revenue raising requirement, you likely reduce economic efficiency). Moreover, subsidization may be much riskier: we know that taxing carbon will reduce its use, whereas subsidizing unknown alternatives may or may not provide a plausible long-run substitute.[12]

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.

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.[13]

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[12] See Lipton and Krauss (2011) for a discussion of the pitfalls of real-world subsidies to alternative energy sources.

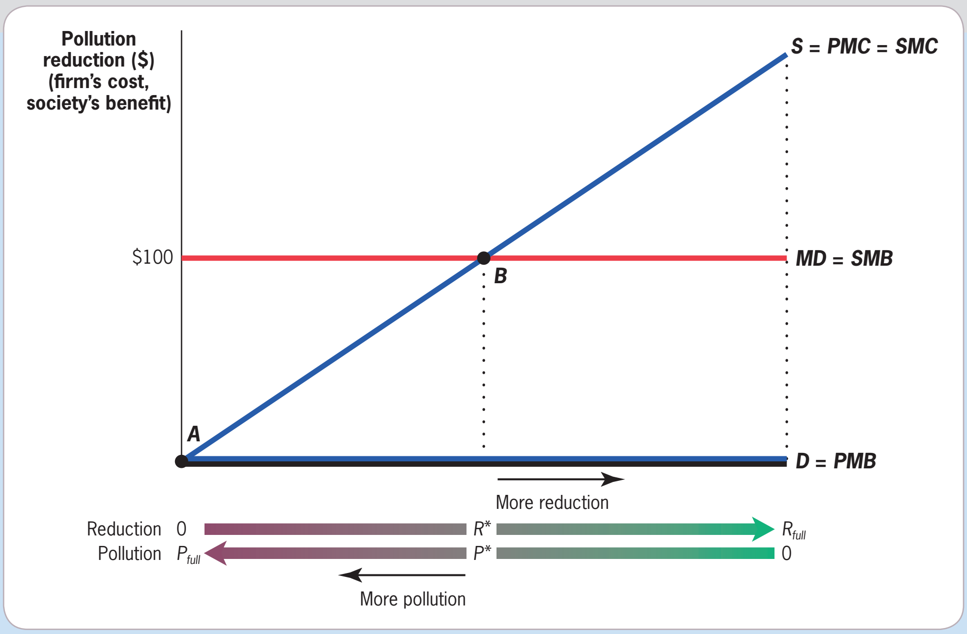
[13] The discussion in this section focuses entirely on the efficiency consequences of tax versus regulatory approaches to addressing externalities. There may be important equity considerations as well, however, that affect the government's decision about policy instruments. We discuss the equity properties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

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

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. Because pollution is the complement of reduction, the optimal amount of pollution is P^*.

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 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 (i.e., 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. Because 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^*: 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^* and pollution of P^*.

Price Regulation (Taxes) Versus 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^* 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^*, to get to the optimal pollution level P^*. 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. 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.

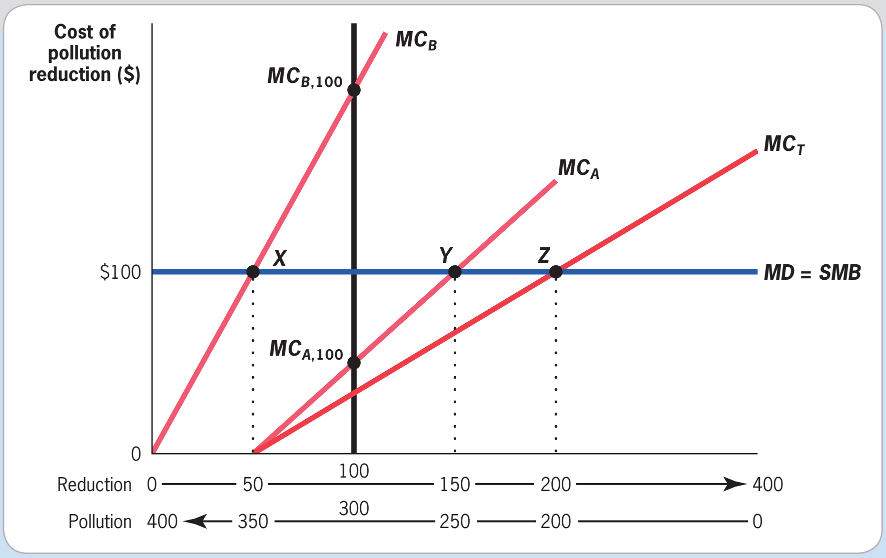
Multiple Plants with Different Reduction Costs

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 the 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 because it has a newer production process. For 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* because 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 and is, therefore, the social marginal cost of reduction. For example, the total marginal cost of a reduction of 50 units is $0 because 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).

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

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 because the marginal cost to Plant B (*MCB*) is so much higher than the marginal cost to Plant A (*MCA*). 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.

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 reductions 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; the 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 that 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 $MC_{A,100}$ because 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

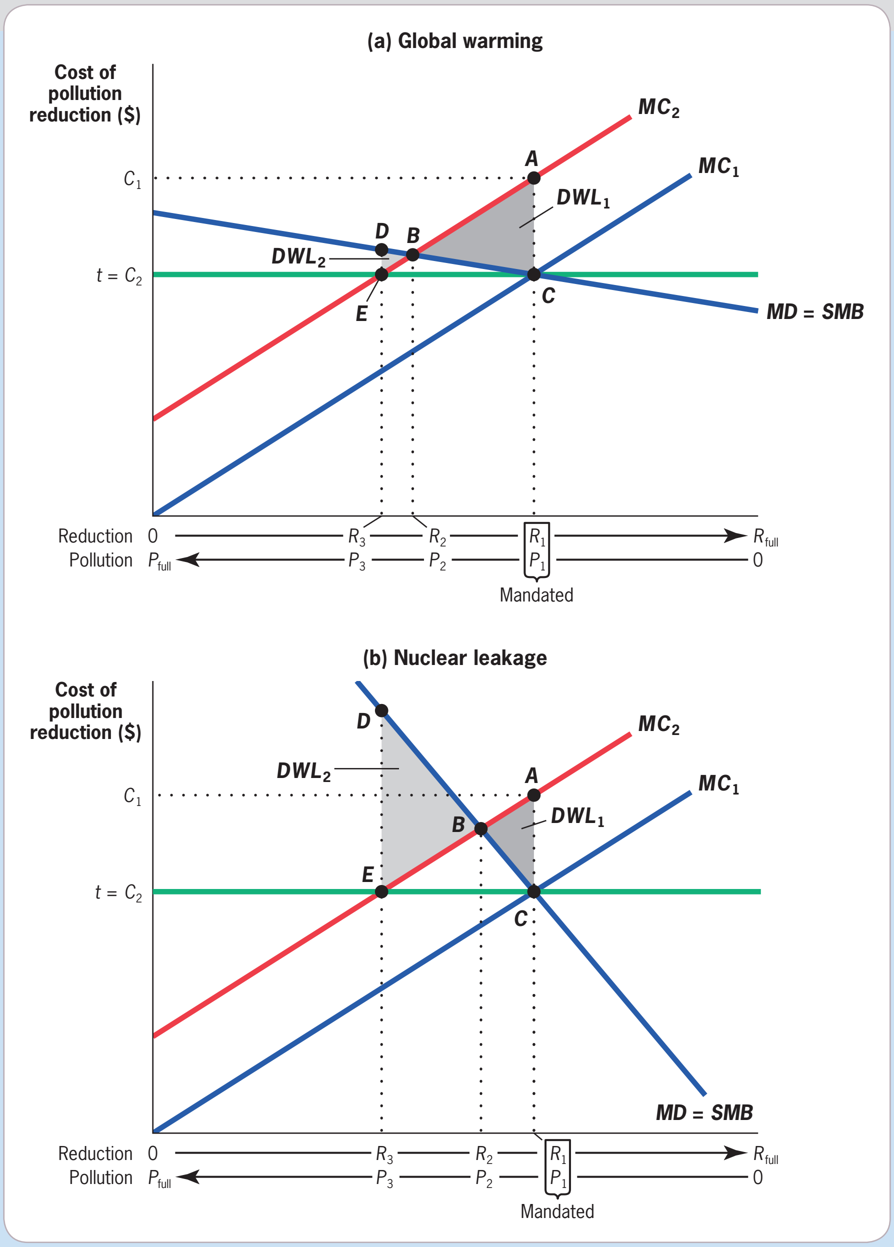
Differences in reduction costs across firms are not the only reason that taxes or regulation might be preferred. Another reason is that the costs or benefits of regulation could be uncertain. Consider two extreme examples of externalities: global warming and nuclear leakage. Figure 5-10 extends the pollution 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 (i.e., 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. Because 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 very 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.

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*).

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. Now, suppose 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. Because 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 ensures 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; thus, it is inefficient in this case to mandate a very costly option for firms.

Price regulation through taxes, on the other hand, ensures 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 Conclusion

Externalities are the classic answer to the "when" question of public finance we studied in Chapter 1: 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 approve new polluting industries more easily 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 $MC = 10 + 30Q$. 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 $120 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 $PMB = 350 - 4Q$ and the private marginal cost associated with its production is $PMC = 6Q$. Furthermore, the marginal external damage associated with this good's production is $MD = 4Q$. 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 $Q = -240 + 2P$. Furthermore, suppose that the marginal external damage of this product is $12 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 $MC = 25 + 2Q$.

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 $MC = 150 + 3Q$. Firm B's marginal costs associated with pollution reduction is $MC = 10 + 9Q$. The marginal benefit of pollution reduction is $MB = 250 - 4Q$.

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 $12w$, while the costs are $3 \times w^2$. The damage to roads is $2 \times w^3$. 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 (e.g., how might the toll depend on the car)?

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 $MB = 620 - 3Q_T$, where Q_T 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?

18. Suppose that the (external) damage done by pollution is known to be $MD = 300 + 5Q$, and the (private) cost and benefit are given by $MC = 100 + 2Q$ and $MB = D_0 - 2Q$, where D_0 is not precisely known.

- **a.** If $D_0 = 1{,}000$, what would be the optimal quantity? What tax would be necessary in order for that to be the equilibrium quantity?
- **b.** Suppose that, based on the result from part (a), a cap-and-trade system is imposed to allow the optimal quantity of pollution to be produced. If $D_0 = 900$, what would be the deadweight loss associated with having the wrong quantity?
- **c.** Suppose that, based on the result from part (a), a tax is imposed to allow the optimal quantity of pollution to be produced. If $D_0 = 900$, what would be the deadweight loss associated with having the wrong tax level?
- **d.** If D_0 is not exactly known, which is likely to give better results, a cap-and-trade system or a tax? What would be the answer to this question if the marginal damage were $300 + 3Q$ instead of $300 + 5Q$?

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CHAPTER 6

Externalities in Action: Environmental and Health Externalities

Questions to keep in mind

- How has public policy toward acid rain affected the environment and the economy?
- How can the world come together to combat climate change?
- What are the appropriate government responses to health externalities such as smoking, drinking, and obesity?

As discussed in the introduction to Chapter 5, the major environmental threat facing the world over the coming century is the warming of our atmosphere and resulting changes in our climate. Responding to this threat, in 2009, the U.S. Environmental Protection Agency (EPA) ruled that it had the power to regulate the major cause of global warming, carbon dioxide (CO_2).[1] But it took more than two years for the EPA to exercise its power, and when it did, the regulations it proposed were immediately and simultaneously criticized as both too invasive and as not strong enough.[2]

The regulations in question were issued by the Obama administration on March 26, 2012, and they restricted greenhouse gas emissions from new power plants in the United States. Power plants are a major source of the gases that cause global warming, representing 37% of total U.S. CO_2 emissions in 2013.[3]

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[1] U.S. Environmental Protection Agency (2012). Visit the EPA to find out more about Clean Power Plan, at http://www2.epa.gov/sites/production/files/2014-06/documents/20140602fs-important-numbers-clean-power-plan.pdf (2015).

[2] The discussion in this section follows Fears (2012) and Plumer (2012).

[3] U.S. Environmental Protection Agency (2012).

The regulation restricted all new power plants to emit no more than 1,000 pounds of CO_2 per megawatt-hour produced. The vast majority of natural gas–powered plants easily meet this standard. But for plants powered by coal, the standard is harder to satisfy. As the *Washington Post* reported, "This effectively means . . . [t]hat it will be impossible to build any new coal-fired power plant in the United States . . . this is a moratorium on all new coal plants."[4]

This restriction on emissions from new power plants was hailed by then-EPA administrator Lisa Jackson as "a common-sense step to reduce pollution in the air, protect the planet for our children and move us into a new era of American energy." And a move away from coal- to natural gas–powered plants offers great potential to reduce carbon emissions: an MIT Energy Initiative study found that such a shift could offer short-term reductions in CO_2 emissions of up to 20%.[5]

At the same time, because the coal industry is a key industry in some parts of the United States, the regulation was quickly denounced by policy makers and politicians. Senator Joe Manchin of West Virginia said, "This EPA is fully engaging in a war on coal, even though this country will continue to rely on coal as an affordable, stable, and abundant energy source for decades to come." More bluntly, Republican presidential candidate Rick Santorum said, "President Obama's environmental agenda kills American jobs, creates higher energy prices, and weakens our nation's security. America is the Saudi Arabia of coal, and we could create our own energy if the government would let us."[6]

This controversy was only heightened in the summer of 2014, when the Obama administration announced the Clean Power Plan, stipulating that the United States will cut annual carbon dioxide emissions from existing power plants by 17% by 2020 and 30% by 2030. The rule provides for a number of options (called "building blocks") to cut carbon emissions and proposes specific emissions rate targets for each state by estimating the extent to which a state can utilize each block. The blocks include improving the efficiency of fossil fuel plants, utilizing more low-CO_2-emitting power sources, expanding the use of renewable energy sources (wind, solar) to generate power, and using electricity more efficiently. Different states will have dramatically different targets, reflecting each state's unique mix of energy-generation resources, energy technology, costs, and emissions reduction potential with regard to each of the blocks. The state of Washington, for example, will have to cut carbon emissions by 72% by 2030, which the EPA deemed reasonable because the state's enormous Centralia coal plant is slated to shut down in the 2020s. By contrast, Indiana will only be required to cut carbon emissions by 20% because it lacks easy access to natural gas.[7] The Supreme Court delayed the plan's progress in June 2015, requiring it to revise its cost-benefit ratio before being upheld. Once the plan goes into place, it will allow states up to two years to submit and implement their strategies to meet the emissions targets.[8]

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[4] Plumer (2012).
[5] U.S. Environmental Protection Agency (2015).
[6] Barringer (2012).
[7] For an overview of the proposed regulations see "Everything You Need to Know About the EPA's Proposed Rule on Coal Plants" (Eilperin and Mufson, 2014a), http://www.washingtonpost.com and "How Obama's Clean Power Plan Actually Works—A Step-by-Step Guide" (Plumer, 2015), http://www.vox.com.
[8] Schlanger (2015).

This rule was praised by environmental groups. Daniel J. Fiorino, who directs the Center for Environmental Policy at American University, said that the approach is a "really nice example of smarter regulation" because it gives the states great leeway in choosing how to meet the federal standard. Similarly, Andrew Steer of the World Resources Institute claimed that the Clean Power Plan is a "momentous development" that "raises the bar for controlling carbon emissions in the United States."[9] The EPA estimates that the rule will cut traditional air pollutants such as sulfur dioxide, nitrogen oxides, and soot by 25% by 2030, yielding a positive externality of between $55 and $93 billion per year until 2030, far outweighing the expected costs of between $7 and $9 billion per year for implementing the plan.[10]

Meanwhile, opponents of the rule argue that Obama's proposed emissions cuts are simply not feasible given current technology. House Speaker John Boehner recently went on record, claiming, "The president's plan is nuts, there's no really succinct way to describe it." He argued that Obama's efforts to address climate change will "ship jobs overseas" and condemn Americans to "higher bills and lower incomes."[11] The U.S. Chamber of Commerce recently released a report outlining that the Clean Power Plan would cost businesses more than $50 billion a year.

In this chapter, we apply the theoretical tools of Chapter 5 to real-world policy issues such as the regulation of CO_2 emissions. We begin by focusing on a different but historically important source of negative environmental externalities—acid rain.

The U.S. experience with acid rain regulation highlights the enormous value of a tool introduced in the previous chapter: emissions trading. Allowing trade within the acid rain regulatory scheme lowered the costs of these regulations by 50% or more. This lesson has proved influential in the debate over global warming. In this chapter, we discuss the 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, especially those caused by cigarette smoking. Health behaviors provide an excellent forum for assessing when actions cause externalities on others (and when they do not), as well as for raising the question of whether actions of an individual that harm only that individual should be regulated by the government.

6.1 The Role of Economics in Environmental Regulation: The Case of 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

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[9] Eilperin and Mufson (2014b).
[10] U.S. Environmental Protection Agency (2015).
[11] Prokop (2014).

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

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.[12]

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 Chapter 5, 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 more than 30 years. The story of this intervention and the effects it has had on the environment, on health, and on the economy provides an excellent example of the possibilities and limitations of government policy toward the environment.

The Damage of Acid Rain

Acid rain causes damage to our environment, our economy, and our health in a variety of ways:[13]

- *Environmental damage:* Many lakes and streams examined in a National Surface Water Survey (NSWS) suffer from chronic acidity, a condition in which water has a constant low pH level. In the survey, the EPA had determined that acid rain causes acidity in 75% of the acidic lakes and about 50% of the acidic streams. Acid rain causes a cascade of effects that harm or kill individual fish, reduce fish population numbers, completely eliminate fish species from a body of water, and decrease biodiversity. Acid rain also 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.[14]
- *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).
- *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.
- *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

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[12] Ellerman et al. (2000), p. 5.
[13] Acid rain information comes from the EPA's website (2015) at http://www.epa.gov/acidrain.
[14] 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.

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. The small size of the particulates can trigger lung, blood vessel, and heart inflammation. Other health effects from exposure include difficulty breathing, coughing, lung damage, aggravated asthma, bronchitis, irregular heartbeat, heart attacks (nonfatal), and cancers.[15] In fact, airborne particulates often contain complex organic materials, including benzene, polychlorinated biphenyls, and polynuclear aromatic hydrocarbons (PAHs), many of which are known suspected carcinogens.[16] Some individuals are particularly at risk, especially those who already have heart and lung diseases, children, and the elderly.

History of Acid Rain Regulation

Regulation of the emissions that cause acid rain began with the **1970 Clean Air Act (CAA),** 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 Chapter 5, the government chose a regulatory (quantity) approach over a tax (price) approach for dealing with this environmental problem.

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

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 CAA were passed, most notably a regulation that mandated a reduction of more than 50% in the level of SO_2 emissions nationwide and

[15] U.S. Environmental Protection Agency (2015.)
[16] Holgate (1999).

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 using the regulatory changes induced by the Clean Air Act. 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 greater than 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

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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.

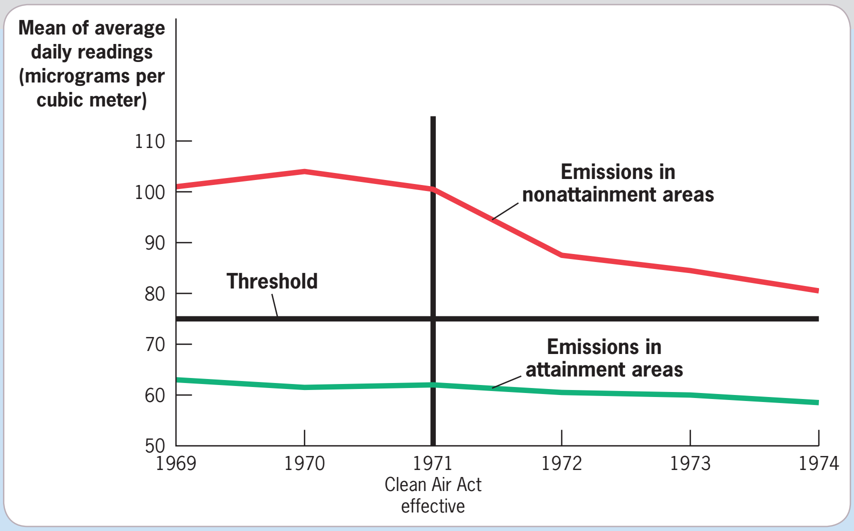
included all plants, even older ones. A key feature of the amendment was that it established an **SO_2 allowance system** that granted plants permits to emit SO_2 in limited quantities, based on their historical fuel utilization.[17] Plants were allowed to buy, sell, and save (for future years) these 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

[17] 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, the EPA would grant Brian only enough emission allowances each year 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.

their first birthday). Infants can develop severe and potentially fatal respiratory problems from particulates in the air.

Chay and Greenstone's findings are striking: infant mortality declined substantially in areas with regulation-induced reductions in emissions, relative to areas in which emissions were not mandated to fall. They found that each 10% decline in particulates led 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, 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 CAA • In the set of counties that had low levels of 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.

Data from: Chay and Greenstone (2003), Figure 2a.

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.[18] On the other hand, the allowance

[18] Perciasepe (1999).

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 forgave them their sins for a price, 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."[19]

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.[20] A wider range of studies finds that the trading program has lowered estimated costs between 33 and 67%.[21]

The CAA 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 interest as well because 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 CAA 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 CAA, 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 CAA 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. And these health improvements may have long-term benefits: Isen et al. (2014) found that those who were protected from air pollution by the 1970 CAA had much higher earnings later in life, amounting to $4,300 more in lifetime earnings for the 1.5 million individuals born into newly protected counties each year.

The trick is to put all of these observations together into a definite conclusion. (We 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.

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[19] McCarthy (1990).
[20] Ellerman et al. (2000), Table 10.5.
[21] Ellerman et al. (2000), p. 296.

6.2 Global Warming

The environmental externality that could potentially cause the most harm to humans is global warming and the resulting changes in the Earth's climate. 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, such as CO_2 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.[22]

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, and thus the magnitude of the greenhouse effect has risen. Since the Industrial Revolution (which took place in Europe and the United States from the eighteenth to nineteenth centuries), for example, the amount of CO_2 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 CO_2 are measured by what the carbon alone would weigh if in solid form, sort of like a chunk of coal). Most of this CO_2 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 since 1951, the most rapid increase in at least 1,000 years (see Figure 5-1, p. 124). 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.

More worrisome are projections for the next century. The average surface temperature of the Earth is likely to increase by 0.5 to 10 degrees Fahrenheit by the end of the twenty-first century, relative to 2005, with a best estimate of 1 to 7.4 degrees. The average rate of warming over each inhabited continent is very likely to be at least twice as great as that experienced during the twentieth century.[23] A temperature rise of 6 degrees would lower global GDP in 2100 by more than 10%, with India, Africa, and western Europe seeing reductions of more than 15%.[24] Temperature rise will also have dramatic implications for biodiversity: a temperature rise of 3% is projected to lead to the extinction of up to 30% of all the world's species.[25] And global warming is projected to increase the severity of extreme weather conditions dramatically: as surface temperatures have increased by 1% since the 1970s, there has been a 75% increase in category 4 or 5 hurricanes.

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

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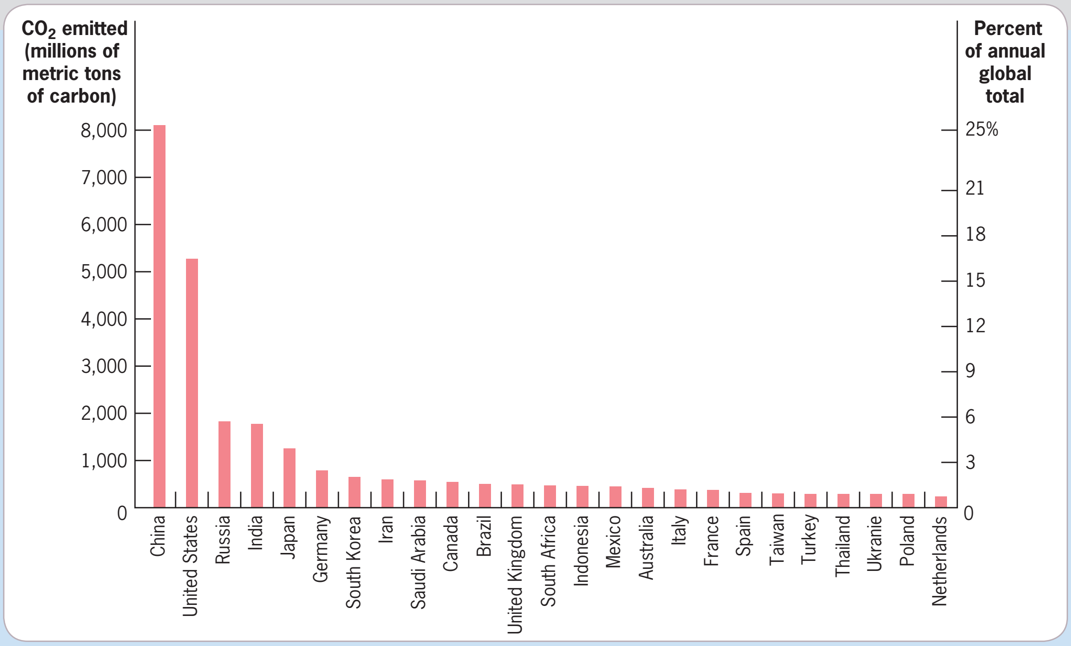
[22] Congressional Budget Office (2003a).
[23] International Panel on Climate Change (2014).
[24] Nordhaus and Boyer (2000), Figure 4.4. The damage to India and Africa will come through the impact of global warming on human health because a number of tropical diseases will be able to spread beyond their 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.
[25] Intergovernmental Panel on Climate Change (2007).

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

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.[26] More recently, in August 2010, a giant ice island covering 100 square miles broke off the Petermann Glacier in northern Greenland; this is the largest chunk of ice calved in the Arctic since 1962.[27] Recent studies have found that the eventual collapse of the West Antarctica Ice Sheet appears likely, leading to another 4 feet of sea level rise over the next several centuries, on top of the existing projected sea level rises.[28]

Figure 6-2 shows how much CO_2 the most polluting nations emit annually by burning fossil fuels, the main source of greenhouse gas emissions. (In the

FIGURE 6-2



Top 25 Fossil Fuel CO_2 Emitters in 2012 • The United States and China together accounted for more than 40% of the world's total CO_2 emissions in 2012.

Data from: U.S. Energy Information Administration, *Total Carbon Dioxide Emissions from the Consumption of Energy, Thousand Metric Tons of* CO_2 (CDIAC).

[26] Revkin (2003). For an interactive illustration of the impacts of global warming around the world, see http://gain.globalai.org/.
[27] *Huffington Post* (2010).
[28] These studies are summarized at http://www.vox.com/2014/5/12/5710440/the-collapse-of-west-antarcticas-glaciers-appears-unstoppable.

United States in 2012, for example, fossil fuels accounted for about 84% of all the energy used.) China and the United States are by far the largest emitters of CO_2, together accounting for more than two-fifths of the world's total. But the high share of emissions for developing countries such as China or India 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 have the same effect on the global environment whether they come from Boston or Bangkok. Moreover, it is the stock of CO_2 in the air, not the level of yearly emissions, that causes warming. Global warming, therefore, is not a problem that can be solved immediately 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.

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 to 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.[29]

Unlike global warming, the CFC problem was showing itself immediately and urgently: by the 1980s, a hole measuring 25 million square kilometers 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 a 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.[30]

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[29] United Nations Environment Programme (2003).
[30] United Nations Environment Programme (2006).

The result is that, after reaching its peak size in 2000 of 30 million square kilometers, the hole in the ozone layer has declined by 9%. It currently is about the same size as it was when it was first discovered, but will continue to recover and return to normal around 2070.[31] 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.

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 more than 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.[32]

These goals were written into a treaty that has since been ratified by 37 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 have implied reducing 2010 emissions by 16%.[33] Nordhaus and Boyer (2000, Table 8.6) estimated that achieving the Kyoto targets would imply a present discounted value cost to the United States of more than $1 trillion. By these authors' estimates, the United States would bear a much higher share of the total world cost of meeting the Kyoto targets than the share that it contributes to annual greenhouse gas emissions. This is because U.S. 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 the natural gas or nuclear-powered plants more frequently used in other nations such as Japan, which produce much lower levels of greenhouse gases).

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.

Can Trading Make Environmental Agreements 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.**

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[31] National Aeronautics and Space Administration (2014).

[32] This is an average that reflects a compromise among that set of nations; the United States, for example, agreed to reduce its emissions 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.

[33] U.S. Environmental Protection Agency (2012). Emissions for 2010 were 6,821.8 Tg CO_2 equivalent, and for 1990, they were 6175.2 Tg CO_2 equivalent.

Under the Kyoto treaty, the industrialized signatories are allowed to trade emissions rights among themselves, so 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.

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%.[34]

This point is illustrated in Figure 6-3. 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.

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

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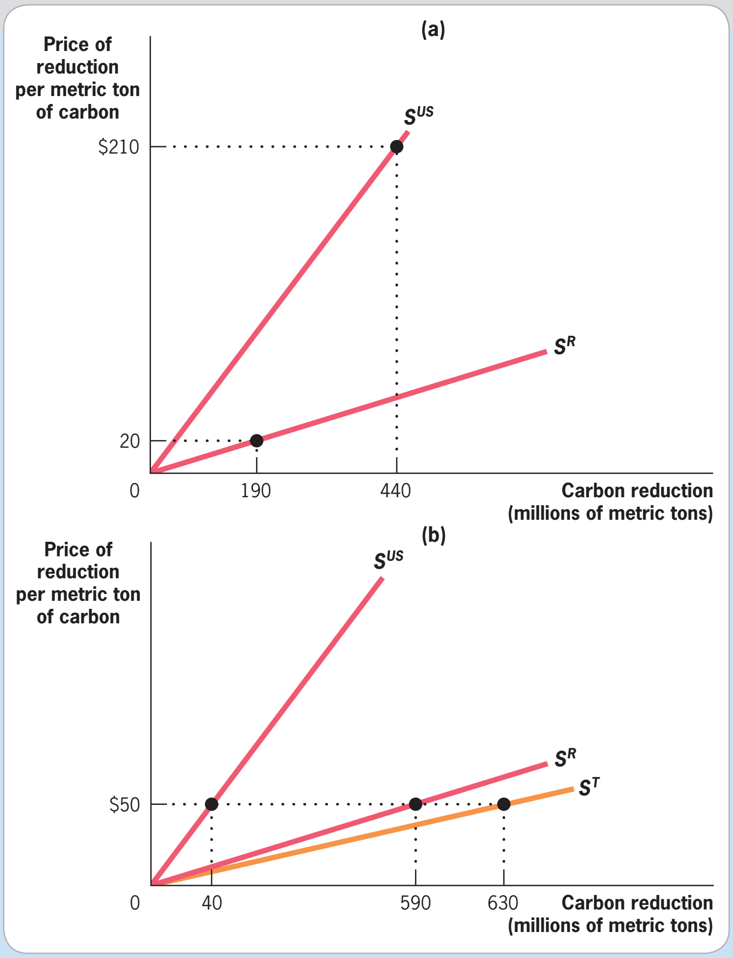
[34] Nordhaus and Boyer (2000), Table 8.5.

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.

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 (because 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 because 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.[35] 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 much 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.[36] 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. 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. The Kyoto targets expired in 2013, and at this point, only the European Union has agreed to continue efforts to meet them. Recent global conferences have replaced the Kyoto targets for other nations with less ambitious voluntary targets with no penalty for exceeding them.

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[35] Nordhaus and Boyer (2000), Figure 7.7.
[36] Nordhaus and Boyer (2000), Table 8.5.

Developments in 2014 and early 2015 have been the most promising since Kyoto, however. In particular, in the fall of 2014, the United States and China, who together produce more than one-third of global greenhouse gas emissions, announced a landmark deal to jointly slow emissions growth. The United States proposed to achieve an economy-wide target of reducing emissions of 26 to 28% below its 2005 level by 2025. China announced the goal of peaking CO_2 emissions and to increase the usage of non-fossil fuels in primary energy consumption to 20% by 2030. The agreement marked the first time China publicly announced goals of reducing CO_2 emissions. Additionally, the two countries agreed to continue other previous joint efforts for climate change, including the U.S.–China Climate Change Working Group (CCWG) that launches initiatives for more emission-friendly alternatives. They also agreed to expand the U.S.–China Clean Energy Research Center by including a joint peer review of inefficient fossil fuel subsidies and increasing funding for the Joint Clean Energy Research and Development. Lastly, the announcement saw to the creation of a new carbon storage project based in China led by both countries.[37] By announcing their plans early, the presidents of both countries hope they can encourage other countries to do the same and announce individual goals and actions by early 2015 to prepare for the 2015 Climate Change Conference in Paris.

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, it is expensive. As we learned in Chapter 5, in such a situation (i.e., 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.[38] 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.

Of course, this discussion focuses on just two types of approaches to addressing global warming. There are a variety of other policy tools as well, ranging from changing how we eat (because methane from cows is a major

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[37] White House Office of the Press Secretary.

[38] A recent report from the CBO discusses in detail the revenue and economic implications of carbon taxation (CBO, 2013).

source of greenhouse gases) to developing new "clean" technologies that can produce goods and services with a lower rate of emissions of gases. Indeed, a recent project sponsored jointly by the British and U.S. governments, as well as others, allows the user to assess the impact of alternative policy interventions on global temperature patterns.[39]

It is important to remember, however, that the use of these alternatives will ultimately be driven by government price and quantity policies. For example, one recent study found that use of clean technologies in automobiles is highly responsive to the cost of higher carbon taxes.[40]

APPLICATION

Congress Takes on Global Warming

In 2009, government initiatives to reduce global warming became a "hot" issue again, thanks to the election of a new Democratic president and to Democratic majorities in the House and Senate. In the House, Democrats Henry Waxman and Edward Markey cosponsored the American Clean Energy and Security Act (ACES), the most far-reaching effort to date to regulate carbon emissions. The bill set a target of reducing emissions to 17% below 2005 levels by 2020 and 83% below 2005 levels by 2050. While much less aggressive than the Kyoto targets, reaching these targets would still represent a major reduction in carbon usage in the United States.

A central feature of the proposal was to allow emissions permits to be traded, a process built on the lessons drawn from basic economics and on the success of trading under the CAA and its amendments. Under ACES, there would be lower limits on the amount of emissions allowed, and firms could comply with the tighter targets in a number of ways:

- They could reduce their emissions.
- They could continue emitting pollutants up to the amount of their purchased emissions permits.
- They could purchase pollution credits to offset their emissions. Such credits would be given to other entities that are not subject to the caps but that take actions to reduce global warming. For example, farmers who plant trees that sequester carbon from the air could receive credits for doing so, and they could sell these credits to a power plant, which could then use the credits to offset their emissions.

The Congressional Budget Office (CBO; 2009) estimated that emissions permits would cost $28 per ton of emissions by 2020. In that year, roughly 80% of the permits would be given away to existing carbon-emitting firms, and 20% would be sold to polluters to raise government revenue. Over time, the share that is sold would rise, reaching 70% by 2035.

ROBERT DODGE/E+/GETTY IMAGES

[39] The "Global Calculator" is available at http://tool.globalcalculator.org.
[40] Aghion et al. (2012).

ACES immediately drew criticism from several sources. First up were those who criticized the bill for raising the cost of energy production because emitting firms would now either need to buy permits, buy credits, or undertake other expensive actions to reduce their emissions. As one critic wrote, "[T]here's no getting around it—higher energy costs will inevitably lead to higher consumer prices and fewer jobs."[41] Indeed, the CBO estimated that the firms that must acquire permits would pass on the costs of doing so to their customers in the form of higher energy prices, with a gross cost to the economy of $110 billion in 2020, or almost $900 per household. To counter this objection, the CBO pointed out that these valuable permits would be initially allocated to emitting firms, and that any money that the firms would receive if they sold their permits could offset their need to raise prices. The CBO estimated that the value of these permits would be $85 billion in 2020, so the net cost in 2020 would be only $25 billion ($110 billion – $85 billion), or $175 per household.[42]

Remember, however, that all such analysis is only a projection, and, as discussed in Chapter 5, because the costs of emission reduction are uncertain, the cost to society of a fixed emissions target could be much higher. The legislation recognized this issue and took several actions to address it, including allowing firms to "bank" any excess emissions permits they had purchased or been issued, allowing firms to meet their targets over a two-year period so they would not have to undertake radical reductions in one given period, and setting up a "strategic reserve" of extra allowances that would be provided to the market if the cost of allowances rose to more than 160% of their projected price (akin to the "escape valve" discussed earlier).

The second source of criticism of ACES came from those who felt that the full value of the allowances should be rebated to consumers, not simply given back to the polluting industries. ACES attempts to address this concern by specifying that polluting utility companies should pass the value of the allocated permits back to consumers. This solution has two problems, however. First, there is no guarantee that the utilities will do so; they may instead use the money raised from the sale of these valuable permits to raise their profitability and thus the return to their investors. Second, if the permit values are passed back to consumers of energy, then ACES may undo the very goal of the legislation, which is to raise the price of energy so that consumers use less of it!

It is for these reasons that economists strongly support not only having tradeable permits, but also determining the initial allocation of permits through auction. That is, instead of directly giving the permits to various polluting firms, the government would hold an auction in which polluting firms would bid against each other for the permits that allow them to emit a specified amount of pollution. By charging polluters for their permits rather than giving them away, the government would simultaneously raise money and raise the prices of energy consumption (which would address the negative externality of global

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[41] *The Washington Examiner* (2009).

[42] The reasons that there is not a zero economy-wide cost are that some of the emissions reduction is met by purchasing offsets from other nations and that there is a resource cost associated with reducing emissions.

warming directly). But, as our earlier discussion suggests, such an approach is less popular with politicians because they would then face opposition from polluting industries (which would have to pay for their permits) and from energy consumers (who would see higher energy prices). Whether the revenue raised from such an auction could be used to offset these criticisms is unclear.

In the case of ACES, politicians apparently felt that this was not possible and the only way to pass the legislation was to give the pollution permits to the polluters rather than raise revenues by selling them. As one reporter wrote, "Instead of auctioning off all the permits to pollute, Waxman-Markey would give many away free, thus decreasing the amount of revenue that could be returned to Americans."[43]

The final concern came from others who felt that the legislation didn't go far enough to address global warming. As one blogger wrote, "A full implementation and adherence to the long-run emissions restrictions provisions described by the Waxman-Markey Climate Bill would result only in setting back the projected rise in global temperatures by a few years—a scientifically meaningless prospect."[44] But President Obama was confident that the bill would allow the United States to turn the corner toward more efficient energy use, saying, "This legislation will finally make clean energy . . . profitable energy."[45] And others agreed that this first step might be transformative. As *New York Times* columnist Thomas Friedman wrote, ". . . if the U.S. government puts a price on carbon, even a weak one, it will usher in a new mindset among consumers, investors, farmers, innovators, and entrepreneurs that in time will make a big difference—much like the first warnings that cigarettes could cause cancer. The morning after that warning, no one ever looked at smoking the same again."[46]

The debate over this legislation on the floor of the House of Representatives was contentious. The bill's opponents continued to portray the bill as a massive tax on U.S. energy consumption; Pennsylvania Republican Joe Pitts said, "No matter how you doctor it or tailor it, it is a tax."[47] Ultimately, on June 26, 2009, the bill passed by a narrow margin of seven votes. There was not enough support in the Senate to bring the bill to a vote, however, partly due to the political problems of raising energy costs during a recession. There has been continued reluctance in recent years to attempt such a broad legislative approach to global warming, motivating the executive actions taken by the Obama administration that were discussed in the introduction to this chapter.

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.

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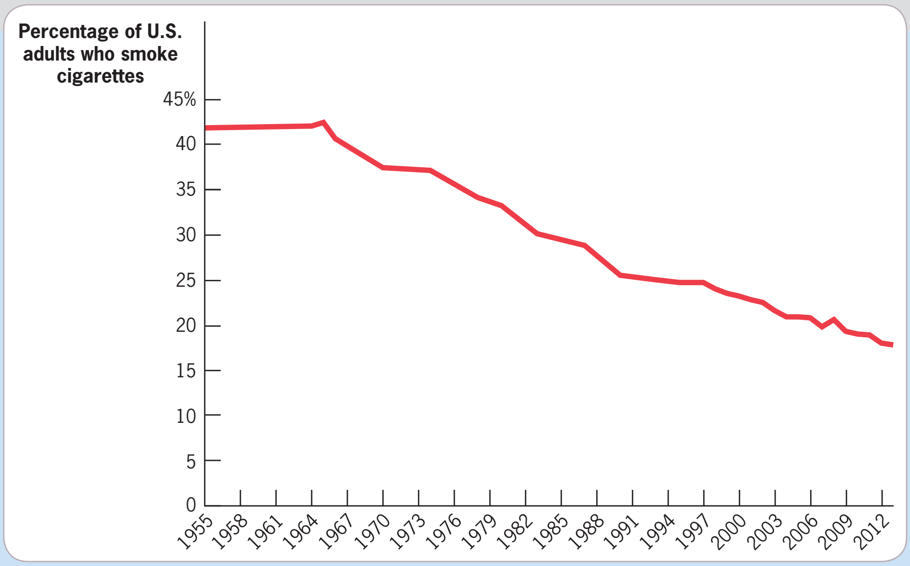
[43] Bandyk (2009).
[44] Knappenberger (2009).
[45] Walsh (2009).
[46] Friedman (2009).
[47] Walsh (2009).

FIGURE 6-4



Annual Percentage of U.S. Adults Who Smoke Cigarettes, 1955–2013 • Before the U.S. Surgeon General's report on the harmful effects of smoking came out in 1964, the rate of smoking in the United States was fairly flat. After, the rate fell steadily.

Data from: Centers for Disease Control and Prevention (2013, 2015).

Cigarette smoking is the single greatest self-imposed health hazard in the United States today. The percentage of Americans who smoke has declined substantially over the past few decades, as shown in Figure 6-4, yet almost 18% of Americans still smoke. This is despite the fact that smoking causes more than 480,000 deaths each year, more than HIV, illegal drug use, alcohol use, motor vehicle injuries, and firearm-related incidents combined. More than ten times as many U.S. citizens have died prematurely from cigarette smoking than have died in all the wars fought by the United States during its history.[48]

Worldwide, the problem is even worse. Of the more than 1 billion smokers alive today, up to half will die of smoking-related disease. By 2030, 8 million persons will die annually from smoking-related disease. At that point, smoking will be the leading cause of overall death (not just preventable death) throughout the world.[49]

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.

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[48] Centers for Disease Control and Prevention (2014).
[49] World Health Organization (2015).

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 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 that 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).

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.

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

Increased Health Costs from Smoking By one estimate, smoking-related disease increases U.S. medical care costs by $170 billion, about 8.7% of the total cost of health care in the United States (Xu et al., 2015). 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 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.

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 that I pay for my group insurance is independent of my smoking behavior. If I smoke, and if I have high medical costs, then the insurance company will have to raise the premiums that 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. This externality is falling over time, however, as companies are more frequently charging an insurance surcharge to their employees who smoke;[50] in addition, the Patient Protection and Affordable Care Act (ACA) allows insurance rates to vary across individuals only by age and by smoking status (but not other health measures).

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 smokers may be less productive in the workplace: they may require more sick leave or more frequent breaks

[50] See, for example, the discussion of Walmart's policy in Abelson (2011).

(for smoking) when at work. One study found that smokers impose \$600 to \$1,100 per year in productivity and absenteeism costs on businesses, and another found that smokers miss 50% more workdays each year due to illness than do nonsmokers.[51] 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 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, and Markowitz (2010) reports that cigarettes cause 3 to 4% of all residential fires in the United States.[52] 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

[51] See Manning et al. (1991), Table 4-11, for absenteeism statistics and p. 139 for a literature review on cost estimates.
[52] Leistikow et al. (2000).

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

costs of smoking roughly $0.52 per pack in 2015 dollars.[53] 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 more than $1 per pack. Of course, these estimates leave out another externality that is potentially important but very difficult to quantify: **secondhand smoke.**

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 $1.28 per pack![54]

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 account fully for the costs to her family members (fails to maximize family utility), then some of the damage that 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.[55]

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 because 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.

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[53] Gruber (2001a), updated to 2015 dollars.
[54] Viscusi (1995), Table 11, updated to 2015 dollars.
[55] See Lundberg et al. (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. More recent evidence is presented in Wang (2013), who finds that transferring property ownership in China to men vs. women significantly affected the consumption of male-favored goods.

Two such features are particularly important: the decision by youths to smoke and the inability of adults to quit. After reviewing these features, we 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 19th birthday, but economics does not yet have a satisfactory model of the behavior of teenagers (as a matter of fact, neither do parents!).[56] 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 up with the seniors 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 the United States express a desire to quit the habit, but many fewer than that actually do quit.
- According to one study, more than 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

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

[56] 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).

(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.

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 that they could cash today over a check for $200 that 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.[57] 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.[58]

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 youths, 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

[57] Ainslie and Haslam (1992).
[58] DellaVigna and Malmendier (2004).

damage from smoking is a **negative internality,** which refers to the damage done to oneself through adverse behavior that is not fully accounted for in decision making. 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.

negative internality The damage done to oneself through adverse behavior that is not fully accounted for in decision making.

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 75 times larger than the typical estimate of the external damage done by smoking.

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.[59]

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.[60] Gruber and Koszegi (2004) calculated 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.

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[59] My child's school recognized the ineffectiveness of warning youths about the very-long-run risks of smoking. His antismoking bookmark had ten reasons not to smoke: 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 that there are short-run costs that offset the short-run benefits of smoking.

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

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 in which 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 mostly because the major externality associated with alcohol consumption is damage due to drunk driving. Every day, almost 30 people in the United States die in motor vehicle crashes that involve an alcohol-impaired driver. This amounts to one death every 48 minutes. The annual cost of alcohol-related crashes totals about $59 billion. In 2013, 10,076 people were killed in alcohol-impaired driving crashes, accounting for nearly one-third (31%) of all traffic-related deaths in the United States.[61] Economists assess the years of life lost from these accidents at a very high value (on the order of $100 billion per year). Even though the drunk driver may lose her license and see her insurance premiums rise, she is unlikely to bear the full costs to society of her action. An estimate for the externalities due to drinking are $1.22 per ounce of ethanol (pure alcohol), which is much higher than current alcohol taxes that amount to only 17¢ to 46¢ per ounce of ethanol, depending on the type of drink (taxes per ounce of ethanol vary across beer, wine, and other alcoholic drinks).[62]

These figures do not include another potentially important externality from drinking: the increased tendency toward violence and crime. A total of 25% of violent crimes and 40% of domestic abuse cases involve victims who report that the perpetrator had been drinking before committing the crime.[63]

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.[64] 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.

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[61] Centers for Disease Control and Prevention (2015).
[62] Manning et al. (1989), updated to 2015 dollars.
[63] U.S. Department of Justice (1998).
[64] See, for example, Markowitz and Grossman (1999); Markowitz (2000a, b); Grossman, Kaestner, and Markowitz (2004); and Markowitz et al. (2005).

The appropriate role for government in regulating drinking is difficult because the externalities due to drinking arise from the share of drinking that results in drunk driving and violence, which is relatively small. 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.[65] A better source of targeting may be raising the age at which youths can access alcohol, as discussed in the Empirical Evidence box.

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 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."[66]

This type of argument has been influential in the recent wave of marijuana legalization in the United States. Marijuana has been legalized for medical purposes in 23 states and the District of Columbia. Full legalization for recreational use is in place in four states (Colorado, Washington, Oregon, Alaska) and the District of Columbia, beginning with Colorado in 2014. Colorado sold roughly $600 million worth of marijuana during the first 11 months of the program, a small fraction of the estimated $2.5 billion market in that state. Since the law passed, there has been a 41% decrease in drug arrests. At the same time, past studies of states with medical marijuana laws have found significant rises in the likelihood of initiating use of marijuana by teens and a rise in the odds of frequent smoking by adults. The Obama administration has stated its opposition to full legalization, arguing that legalization creates

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[65] A recent study by Cook and Durrance (2013) finds that doubling the federal excise tax on alcohol in 1991 reduced accident fatalities by 4.7%, or almost 7,000 in one year.
[66] Friedman (1972).

EMPIRICAL EVIDENCE

The Effect of Legal Drinking at Age 21

In the United States today, the legal drinking age is 21, but in many states, it was lowered to 18, 19, or 20 during the early 1970s, before being normalized back to age 21 in the late 1980s. One concern with a lower drinking age is that youths are particularly susceptible to the internalities and externalities of drinking, particularly with respect to drunk driving. At the same time, others argue that a drinking age of 21 isn't stopping youth drinking and may actually be making things worse. The former president of Middlebury College in Vermont, John McCardell, said during his appearance on the TV show *60 Minutes,* "It hasn't reduced or eliminated drinking. It has simply driven it underground, behind closed doors, into the most risky and least manageable of settings." McCardell says the law has created a dangerous culture of irresponsible and reckless behavior and unsupervised binge and extreme drinking.[A]

So does the drinking age matter? Addressing this question by simply comparing drinking rates above and below age 21 would not be convincing because those over age 21 may have different tastes for drinking than those below age 21. Suppose, for example, that the taste for alcohol rises with age. Then we might find that drinking rises after age 21 but that this increase has nothing to do with legality. If noncomparability due to differing tastes for drinking by age is the source of the difference, rather than the difference in legal status, then our estimates of the effect of the drinking age on drinking would be biased. Recent research, however, has suggested two interesting empirical strategies for addressing this noncomparability issue.

The first is to use the fact that states changed their drinking ages at different times in the 1980s as they moved from lower drinking ages toward a nationally uniform standard of age 21. This provides an excellent quasi-experiment, in which the treatment group is states that raise their drinking ages and the control group is states that don't. If the drinking age matters for drinking, then drinking should fall among those people between the old drinking age and age 21 when the law changed, relative to states where the law did not change.

A number of studies have assessed this quasi-experiment and have found that raising the drinking age not only deterred youth drinking, but also had other important effects. Carpenter and Dobkin (2011) summarized the evidence and reported that a lower drinking age led to 6 to 17% more drinking among 18- to 20-year-olds. Cook and Moore (2001) found that a lower drinking age led not only to more drinking among youths, but also that as those youths aged, they drank more. That is, those who start earlier are more likely to drink later in life. Carpenter and Dobkin (2011) found that lower drinking ages are associated with a 17% increase in the rate of motor vehicle deaths for 18- to 20-year-olds. And Watson and Fertig (2008) found that lower drinking ages led to worse outcomes for births to teen mothers, including low birth weight and premature births.[B]

The second empirical strategy is to contrast outcomes in recent data right around the 21st birthday. While those who are over 21 may be different in general than those under age 21, those who are observed in the few days before their 21st birthday should be very similar to those in the few days after their 21st birthday—except for the fact that the latter group can drink legally. By comparing the outcomes among those comparable groups just before and after their 21st birthday, researchers can derive a causal estimate of the impact of legal drinking on outcomes through what is called a regression discontinuity approach.

This approach is illustrated in Figure 6-5, from Carpenter and Dobkin (2009). The ***x*** axis of this figure shows age in monthly intervals. The bottom line (in red) graphs the proportion of days on which individuals have a drink (and the quantities are denoted on the left-hand vertical axis). The points in the figure are the actual monthly averages by month of age. The solid line is a regression line of the type discussed in Chapter 3, but where the regression line is estimated separately for ages up to 21 and ages over 21. What is clear from this diagram is that there is a discontinuous shift at age 21—a clear jump in the proportion of days drinking at the 21st birthday.

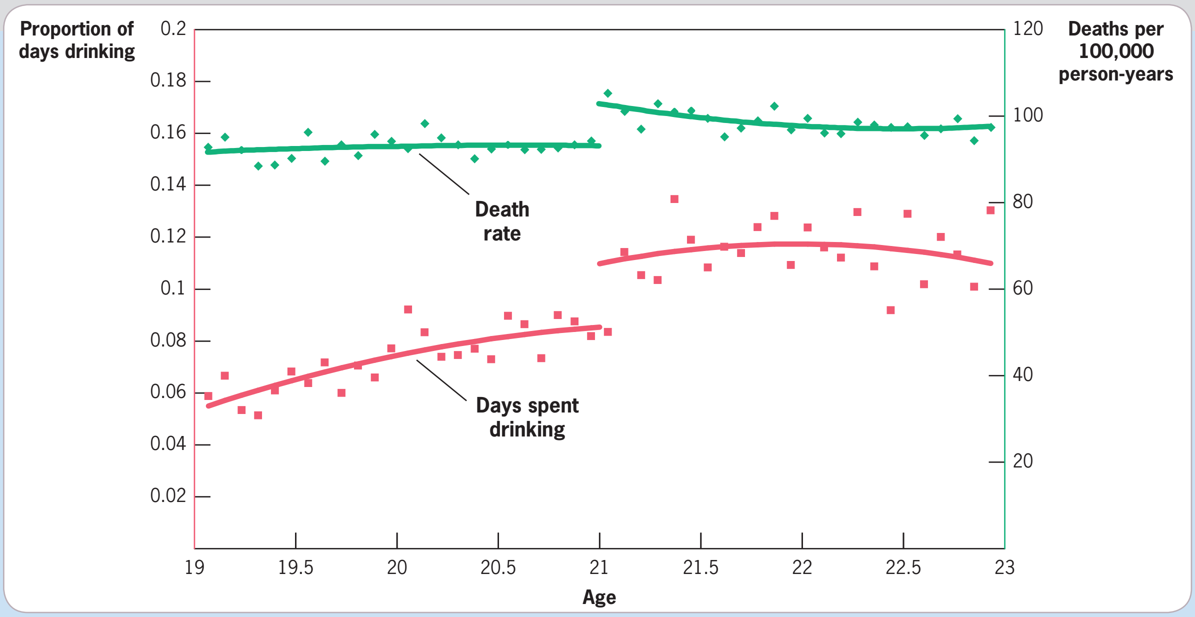
[A] CBS News (2009).
[B] Nilsson (2008) used data from an expansion in access to alcohol in Sweden to show that such reductions in infant health may have negative effects on outcomes such as educational attainment and earnings.

ROBERT DODGE/E+/GETTY IMAGES

Regression analysis that uses the actual birthday, rather than just month of birth, shows that those individuals just over age 21 spend about *30%* more days drinking that those just below age 21.[C] This sizeable discontinuity suggests that there is an effect of legalization at age 21.

The top line (in green) repeats this exercise for a different outcome: death rates (the quantities denoted on the right-hand vertical axis). Once again, there is a striking jump in death rates at age 21, with death rates just after the 21st birthday being 9% higher than just before. That is, the higher numbers of people drinking just after becoming legal is associated with higher rates of mortality. The authors also show that these mortality effects derive largely from higher alcohol-related driving deaths. Using a similar approach, Carrell, Hoekstra, and West (2011) showed that academic performance also suffers upon reaching the drinking age. It is clear from these empirical analyses that lowering the drinking age in the United States does matter and has serious adverse effects on those aged 18 to 20.[D]

FIGURE 6-5



Changes in Drinking and Mortality Around Age 21 • There is a strong "regression discontinuity" around age 21 for both the proportion of days spent drinking and the death rate.

Data from: Carpenter and Dobkin (2009).

[C] To eliminate any celebration-related effects, the analysis included control variables for the day of the 21st birthday itself and the day after.
[D] A recent study by Lindo et al. (2014), however, finds no effect of changes in drinking age on traffic accidents in a region of Australia with particularly stringent drunk-driving laws, suggesting the potential for substitution across types of drinking regulations.

negative social costs that outweigh any reduced spending on prosecuting and jailing offenders for sale and use of marijuana (and any increased revenue from taxes on legal marijuana).[67]

Yet, despite the move to legalize marijuana, broader drug legalization remains a radical idea in most nations, including the United States. 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.[68]

APPLICATION

Public Policy Toward Obesity

A potential health externality that has recently attracted significant attention in the United States and elsewhere is obesity. *Obesity* is defined as having a Body Mass Index (BMI) well above the norm for one's age. The BMI measures the ratio of height to weight. There has been an enormous rise in obesity in the United States: the share of the adult population classified as obese has risen from 12% in 1960 to 35.1% in 2012.[69] While the United States is gaining weight at a more rapid rate than other developed countries, the general rise in obesity is a global phenomenon; the World Health Organization (WHO) reports that about 600 million adults worldwide are obese, or more than one of every ten adults on the planet.[70]

Why is obesity on the rise? Studies have shown that the blame lies with increased caloric intake and reduced physical activity. Caloric intake is rising naturally as incomes rise, and there has been a shift over time from healthy foods (which tend to be preparation-intensive) to unhealthy ones (which are readily available and easier to prepare). The ready availability may especially contribute to obesity when individuals suffer from "self-control" problems that leave them susceptible to easy, low-cost avenues for weight gain. A number of studies show that individuals will eat more, for example, if more is placed in front of them, or if the plate is larger so that it appears that there is less food; as Downs et al. (2009) argue, many individuals are irrationally sensitive to external cues (how full their plate is) relative to their internal cues (how full they are), which should matter most. Another study by Read and van Leeuwen (1998) found that individuals were willing to commit to eating healthier in the future, but when faced with immediate choices, they overturned their earlier commitments and chose less healthy options. In addition, just as caloric intake is rising, physical activity is falling. Industrialized societies have moved

[67] Data from National Conference of State Legislatures (2015); the White House; and Wen et al. (2014).
[68] For an excellent overview of the issues around drug legalization, see Donohue et al. (2011).
[69] Centers for Disease Control and Prevention (2015).
[70] World Health Organization (2015).

from a situation in which individuals are paid to exercise (through jobs that require physical labor and activity) to one in which individuals must pay to exercise (because jobs are sedentary and exercise must come at the cost of foregone leisure time and often at the cost of paid gym memberships).

Public policy makers should care about this rise in obesity because it has both enormous externalities and internalities. Indeed, the fastest growing public health problem in the United States 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. In 2012, 29 million Americans, or 9.3% of the U.S. population, had diabetes, and 37% of the adult population was prediabetic.[71] The number one factor driving the rise in diabetes is the rise in obesity and inactive lifestyles in the United States.

When all the negative health effects associated with obesity are taken into account, the most recent estimates suggest that obesity-related illness may cost the United States $147 billion per year in medical costs.[72] Within 50 years, obesity will likely shorten the average life-span by at least two to five years, a higher impact than that of cancer or heart disease.[73] 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.

Understanding why obesity is rising and the harm it is causing is easy, however, compared to deriving proper policy responses to the problem. There have been a number of different approaches to using public policy tools to reduce obesity, but none has proven highly successful to date.

The first is to change the nature of food supply by making healthier foods more readily available, particularly in low-income "food deserts" where options for healthy eating had previously been limited. But such efforts have so far failed to change eating behavior. The city of Philadelphia, for example, invested millions in new stores to provide healthier options for lower-income areas of the city. Yet a recent study found that the availability of such stores did nothing to change eating habits among residents, while other research has shown that while nutritional food is less available in low income neighborhoods, this only explains a small fraction of the reason nutrition is worse in disadvantaged communities.[74]

Another approach is to tax or even ban unhealthy foods. Addressing obesity through taxing food, however, is much more difficult than addressing smoking because while every cigarette is bad for you, clearly some food consumption is good for you! So a simple tax on calories could do more harm than good by deterring low-income families from getting enough nutrition. More generally, there is a very complicated relationship between different types of food

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[71] Centers for Disease Control and Prevention (2014).
[72] Finkelstein, Trogdon et al. (2009).
[73] Olshansky (2005).
[74] See Kliff (2014) and Handbury et al. (2015). For a more detailed essay of the difficulty of changing eating habits in low-income communities through new grocery options, see McMillan (2014).

consumption and health; for example, as Rosin (1998) writes, "Measuring fat content is not always practical. Hamburger meat has a certain percentage of fat, but most of it would melt away during grilling. And what about sugary no-fat snacks such as soda and candy?" Another complication with taxing food inputs is illustrated by the case of Denmark, which imposed a tax on saturated fat content in foods in 2011; this tax was repealed one year later when it led to a huge increase in Danes shopping in other nations for fatty foods.[75]

This has led some communities to turn instead to an outright ban on unhealthy food stuffs, such as artificial "trans-fats," which are found in baked goods such as pastries, cookies, and many other desserts and in fried foods such as French fries and chicken nuggets. Citing the fact that trans-fats are "chemically modified food ingredients that raise levels of a particularly unhealthy form of cholesterol and have been squarely linked to heart disease," the NYC Board of Health voted in December 2006 to adopt the first significant municipal ban on the use of trans-fats.[76] Denmark limited the use of industrially produced trans-fats as far back as 2003, and trans-fats have been virtually purged from the Danish people's diets.[77] In the United States, the Food and Drug Administration recently announced that it was phasing out partially hydrogenated oils, the main source of trans-fats.[78]

Perhaps the easiest cases to address, and major targets of policies to date, have been schools and childhood obesity. There has been increasing access to junk food in schools in the United States, perhaps driven by financial need because schools profit from selling these foods. One study found that a 10 percentage point increase in probability of accessibility to junk food leads to 1 percentage point increase in the average student's BMI; this study estimates that access to unhealthy school food options has accounted for one-fifth of the increase in average BMI among adolescents between 1990 and 2000 (Anderson and Butcher, 2005). Policies to remedy this trend include restricting the sale of junk food in schools and reforming the structure of school meal plans to focus on more healthy food options. To increase physical activity, some policies require more rigorous school physical education programs.

The major focus of policies to address obesity has been through improved information and targeting of the substances most closely linked to obesity. For example, in July 2008, New York City enforced a law requiring all chain restaurants (those with 15 or more establishments) to display calories on their menus or face a fine ranging from $200 to $2,000 (Sorrel, 2009). A study of the early implementation of this regulation found that it led to a small but statistically significant decrease in the calories per food transaction, although it remains to be seen whether this translates into lower obesity among New York restaurant-goers.[79] The Affordable Care Act mandated that calorie labeling be in place by November 2015 at all chain restaurants, vending machines, and food retail establishments with more than 20 locations.

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[75] Kliff (2012a).
[76] Lueck and Severson (2006).
[77] Kliff (2011).
[78] Ferdman (2015).
[79] Bollinger et al. (2011).

A more successful approach may be to engage consumers directly in self-control strategies. Schwartz et al. (2012) found that when consumers were directly offered the opportunity to downsize their starchy side portions at a Chinese restaurant, a sizeable fraction chose to do so and did not offset this with more calories consumed elsewhere in the meal. And Bedard and Kuhn (2013) found that labeling receipts with personalized, lower-calorie ordering suggestions (e.g., substituting ham for sausage or frozen yogurt for ice cream) led to a modestly sized switch to the suggested alternative in future visits to the restaurant.

Another popular target for policies in this area has been sugary drinks. Studies show that consumption of sugary beverages has nearly tripled from 1980–2000, and by 1998, Americans were consuming more than a gallon of soft drinks a week. Today, consumption has dropped to 450 cans a year, or about 0.8 gallon a week (Suddath and Stanford, 2014). Nonetheless, this figure is still huge. A number of states are considering taxes on sugary sodas. New York City proposed an alternative strategy in 2011, seeking federal permission to ban the use of publicly provided food subsidies for the purchase of sugary soda, but the request was denied. New York City also proposed a ban on the sale of large sugared soft drinks, but the request was rejected by the state's highest court.[80]

In a more aggressive approach, some states and nations have moved directly to charging individuals for being obese or for not caring for their weight. In 2011, then-Governor Jan Brewer proposed an annual $50 Medicaid charge on patients who were obese. The fee would be levied on obese and other high-risk patients only if the identified patient failed to improve her health.[81] In 2008, Japan's Ministry of Health passed mandates requiring local governments and employers to add a "waist measurement test" to mandatory annual checkups for adults. Those who fail the test with waistlines exceeding preset limits must take corrective measures, while local governments and companies whose populations do not meet specified guidelines face financial penalties.[82] Other states and employers are providing financial incentives for employees to enroll in wellness programs that will help them manage their weight. However, a recent study of employees who participated in yearlong health promotion programs that offered financial rewards for weight loss showed a steady, but not significant, loss in weight (Cawley and Price, 2009). ■

Summary

Regulating other health behaviors raises many issues similar 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.

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[80] Grynbaum (2014).
[81] Adamy (2011).
[82] Onishi (2008).

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 distinguishing 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 externalities only, or externalities *and* 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 CAA 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 a 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 CAA 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 on 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. e Think about the concerns about the original CAA described in the text. To what degree did the 1990 amendments to the act address these concerns? Explain your answer.

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

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

7. Some observers argue that since CO_2 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 more than 90% of the total world cost of achieving the Kyoto targets for greenhouse gas emission reductions. Explain how this can be so when the United States produces only about a quarter of the world's greenhouse gases.

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

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

ADVANCED QUESTIONS

11. Why does the approach of Chay and Greenstone (2003) 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 CAA. 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 to 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 that 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?