After studying this chapter, you will be able to:

- Explain why external costs bring market failure and too much pollution and how property rights, pollution taxes, emission charges, and marketable permits might achieve an efficient outcome
- Explain the tragedy of the commons and its possible solutions

17 ECONOMICS OF THE ENVIRONMENT

We burn huge quantities of fossil fuels—coal, natural gas, and oil—that cause acid rain and global warming. We dump toxic waste into rivers, lakes, and oceans. These environmental issues are simultaneously everybody's problem and nobody's problem. How can we take account of the damage that we cause others every time we turn on our heating or air-conditioning systems?

More and more people with ever-increasing incomes demand ever-greater quantities of most goods and services. One item that we demand more and more of is fish grown wild in the ocean. The fish stocks of the world's oceans are not owned by anyone. They are common resources and everyone is free to use them. But we are overusing our fish stocks and bringing some species to extinction. Must the price of fish inevitably keep rising? What can be done to conserve the world's fish stocks?

In this chapter, we study the problems that arise because many of our actions impose costs on other people in ways that we do not take into account when we make our own economic choices. We focus on two big issues—air pollution and overfishing. In *Reading Between the Lines* at the end of the chapter, we look at the effects of a carbon tax designed to lower carbon emissions and address global warming and climate change.

Negative Externality: Pollution

Can each individual be relied upon to make decisions that influence the Earth's carbon-dioxide concentration in the social interest? Must governments change the incentives we face so that our self-interested choices are also in the social interest? How can governments change incentives? These questions about climate change that we posed in Chapter 1 (see p. 6) involve *external costs* and this chapter answers them.

This chapter also studies another environmental problem that requires public choices: the overuse and sometimes the depletion of renewable natural resources.

We first study the external costs of pollution and begin with a quick review of the production activities that pollute our environment.

Sources of Pollution

Economic activity pollutes air, water, and land, and these individual areas of pollution interact through the ecosystem. The three biggest sources of pollution are road transportation, electricity generation, and industrial processes.

A common belief is that our advanced industrial economy is creating ever more pollution. But for many pollutants, in the rich countries that include the United States, pollution is less serious today that it was in earlier years (see *Economics in Action* below for a description of the trends in air pollution).

Effects of Pollution

While the facts about the sources and trends in air pollution are not in doubt, there is disagreement about the effects of air pollution. The least controversial is acid rain caused by sulphur dioxide and nitrogen oxide emissions from coal- and oil-fired generators of power stations. Acid rain begins with air pollution, and it leads to water pollution and damages vegetation.

More than 180 others airborne substances (suspended particulates) such as lead from leaded gasoline have been identified, which in sufficiently large concentrations, are believed to cause cancer and other life-threatening conditions.

Many scientists believe that carbon dioxide emissions are a major cause of global warming and climate change.

The effects of pollution mean that production and consumption decisions impose costs that are not taken fully into account when decisions are made. You are now going to see how economists analyse these decisions and solve the pollution problem.

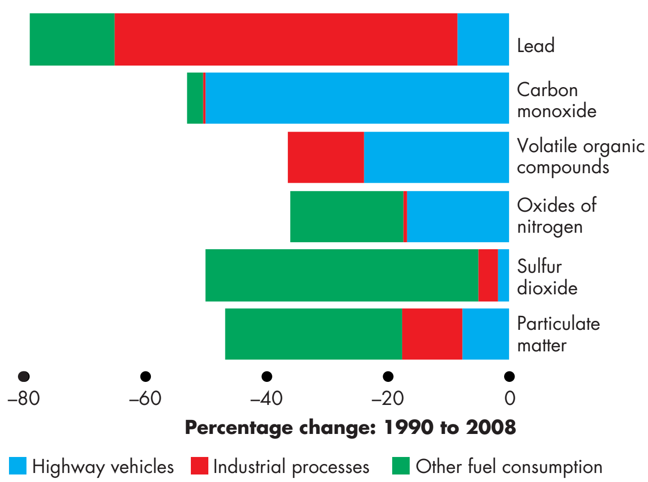
Economics in Action

U.S. Air Pollution Trends: Cleaner and Safer

The figure shows the percentage changes in the concentrations of six air pollutants between 1990 and 2008 and their economic sources. All of these pollutants decreased.

These reductions in air pollution are more impressive when they are seen against the trends in economic activity. Between 1990 and 2008, total production in the United States increased by 66 percent, vehicle miles traveled increased by 40 percent, and the population increased by 20 percent.

The Clean Air Act has brought regulations that cut emissions of carbon monoxide, volatile organic compounds, oxides of nitrogen, sulfur dioxide and particulate matter to around a half of their 1990 levels. And economic actions that you will learn about in this chapter almost eliminated lead from highways and industrial processes.



Six Air Pollutants and their Economic Sources

Source of data: Latest Findings on National Air Quality: Status and Trends through 2008, United States Environmental Protection Agency, http://www.epa.gov/air/airtrends/2010/report/airpollution.pdf

Private Cost and Social Cost of Pollution

To study the economics of the external costs that arise from pollution, we distinguish between the private cost and the social cost of production.

A *private cost* of production is a cost that is borne by the producer of a good or service. *Marginal cost* is the cost of producing an *additional unit* of a good or service. So **marginal private cost** (*MC*) is the cost of producing an additional unit of a good or service that is borne by its producer.

An *external cost* is a cost of producing a good or service that is *not* borne by the producer but borne by other people. A **marginal external cost** is the cost of producing an additional unit of a good or service that falls on people other than the producer.

Marginal social cost (*MSC*) is the marginal cost incurred by the producer and by everyone else on whom the cost falls—by society. It is the sum of marginal private cost and marginal external cost. That is,

$$MSC = MC + \text{Marginal external cost.}$$

We express costs in dollars, but we must always remember that a cost is an opportunity cost—something real, such as clean air or a clean river, is given up to get something.

Valuing an External Cost Economists use market prices to put a dollar value on the cost of pollution. For example, suppose that there are two similar rivers, one polluted and the other clean. Five hundred identical homes are built along the side of each river. The homes on the clean river rent for $2,500 a month, and those on the polluted river rent for $1,500 a month. If the pollution is the only detectable difference between the two rivers and the two locations, the rent decrease of $1,000 per month is the cost of the pollution. With 500 homes on the polluted river, the external cost of pollution is $500,000 a month.

External Cost and Output Figure 17.1 shows an example of the relationship between output and cost in a chemical industry that pollutes. The marginal cost curve, *MC*, describes the marginal private cost borne by the firms that produce the chemical. Marginal cost increases as the quantity of chemical produced increases.

If the firms dump waste into a river, they impose an external cost on other users of the river. We will assume that the marginal external cost increases with the amount of the chemical produced.

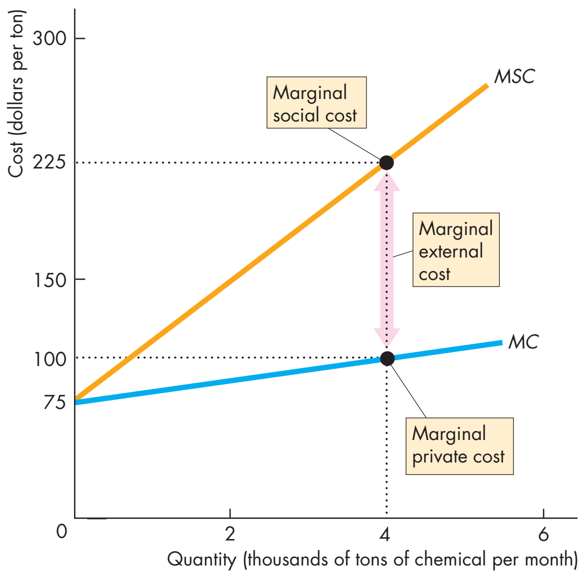
The marginal social cost curve, *MSC*, is found by adding the marginal external cost to the marginal private cost. So a point on the *MSC* curve shows the sum of the marginal private cost of producing a given output and marginal external cost created.

For example, when the chemical industry produces 4,000 tons of chemical a month, its marginal private cost is $100 a ton and the marginal external cost is $125 a ton, so the marginal social cost is $225 a ton.

In Fig. 17.1, when the quantity of chemical produced increases, the amount of pollution increases and the external cost of pollution increases.

Figure 17.1 shows the relationship between the quantity of chemical produced and the cost of the pollution it creates, but it doesn't tell us how much pollution the chemical industry creates. That quantity depends on the quantity of the chemical produced, which depends on supply and demand in the market for the chemical. We now look at that market.

FIGURE 17.1 An External Cost



The *MC* curve shows the marginal private cost borne by the factories that produce a chemical. The *MSC* curve shows the sum of marginal private cost and marginal external cost. When output is 4,000 tons of chemical a month, marginal private cost is $100 a ton, marginal external cost is $125 a ton, and marginal social cost is $225 a ton.

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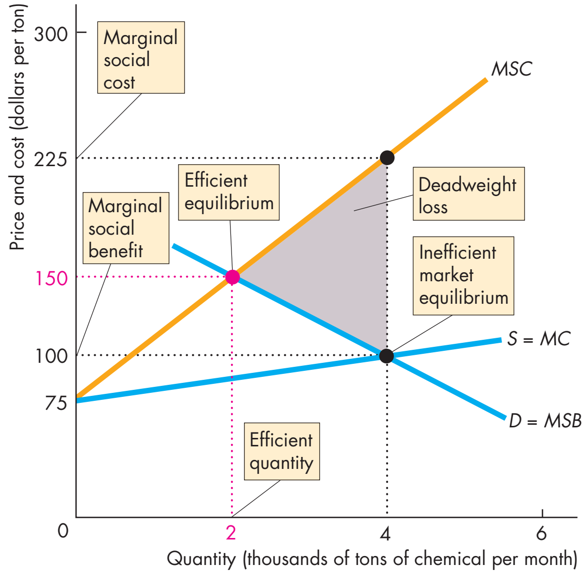
Production and Pollution: How Much?

When an industry is unregulated and free to pollute, the amount of pollution it creates depends on the market equilibrium price and quantity of the good produced. In Fig. 17.2, the demand curve for a pollution-creating chemical is *D*. This curve also measures the marginal social benefit, *MSB*, from the chemical. The supply curve of the chemical is *S*. This curve also measures the producers' marginal private cost, *MC*. The supply curve is the marginal private cost curve because when firms make their production and supply decisions, they consider only the costs that they will bear. Market equilibrium occurs at a price of $100 a ton and 4,000 tons of chemical a month.

This equilibrium is inefficient. You learned in Chapter 5 that the allocation of resources is efficient when marginal social benefit equals marginal social cost. But we must count *all* the costs—private and external—when we compare marginal social benefit and marginal social cost. So with an external cost, the allocation is efficient when marginal social benefit equals marginal *social* cost. This outcome occurs when the quantity of chemical produced is 2,000 tons a month. The unregulated market overproduces by 2,000 tons of chemical a month and creates a deadweight loss shown by the gray triangle.

How can the people who live by the polluted river get the chemical factories to decrease their output of chemical and create less pollution? If some method can be found to achieve this outcome, everyone—the owners of the chemical factories and the residents of the riverside homes—can gain. Let's explore some solutions.

FIGURE 17.2 Inefficiency with an External Cost



The market supply curve is the factories' marginal private cost curve, *S* = *MC*. The market demand curve is the marginal social benefit curve, *D* = *MSB*. The market equilibrium occurs at a price of $100 a ton and 4,000 tons of chemical a month This market outcome is inefficient because marginal social cost exceeds marginal social benefit. The efficient quantity of chemical is 2,000 tons a month. The gray triangle shows the deadweight loss created by the pollution.

myeconlab animation

Property Rights

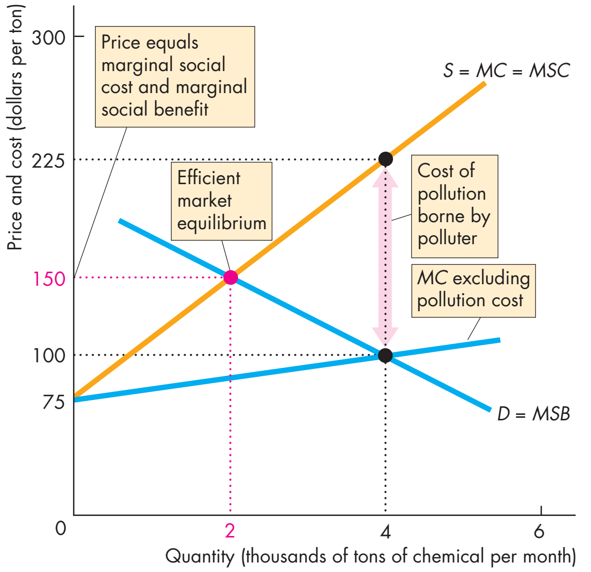
Sometimes it is possible to reduce the inefficiency arising from an external cost by establishing a property right where one does not currently exist. **Property rights** are legally established titles to the ownership, use, and disposal of factors of production and goods and services that are enforceable in the courts.

Suppose that the chemical factories own the river and the 500 homes alongside it. The rent that people are willing to pay depends on the amount of pollution. Using the earlier example, people are willing to pay $2,500 a month to live alongside a pollution-free river but only $1,500 a month to live with the pollution created by 4,000 tons of chemical a month. If the factories produce this quantity, they lose $1,000 a month for each home for a total of $500,000 a month. The chemical factories are now confronted with the cost of their pollution—forgone rent from the people who live by the river.

Figure 17.3 illustrates the outcome by using the same example as in Fig. 17.2. With property rights in place, the *MC* curve no longer measures all the costs that the factories face in producing the chemical. It excludes the pollution costs that they must now bear. The *MSC* curve now becomes the factories' marginal private cost curve *MC*. The factories bear all the costs, so the market supply curve based on all the costs is the curve labeled *S* = *MC* = *MSC*.

Market equilibrium now occurs at a price of $150 a ton and 2,000 tons of chemical a month. This outcome is efficient. The factories still produce some pollution, but it is the efficient quantity.

FIGURE 17.3 Property Rights Achieve an Efficient Outcome



With property rights, the marginal cost curve that excludes pollution costs shows only part of the producers' marginal cost. The marginal cost of producing the chemical now includes the cost of pollution—the external cost. So the producers' supply curve is $S = MC = MSC$. The market equilibrium now occurs at a price of $150 a ton and 2,000 tons of chemical a month. This outcome is efficient because marginal social cost equals marginal social benefit. The pollution created is not zero, but it is the efficient quantity.

myeconlab animation

The Coase Theorem

Does it matter how property rights are assigned? Does it matter whether the polluter or the victim of the pollution owns the resource that might be polluted? Until 1960, everyone thought that it did matter. But in 1960, Ronald Coase (see p. 413) had a remarkable insight, now called the Coase theorem.

The **Coase theorem** is the proposition that if property rights exist, if only a small number of parties are involved, and if transactions costs are low, then private transactions are efficient. There are no externalities because the transacting parties take all the costs and benefits into account. Furthermore, it doesn't matter who has the property rights.

Application of the Coase Theorem In the example that we've just studied, the factories own the river and the homes. Suppose that instead, the residents own their homes and the river. Now the factories must pay a fee to the homeowners for the right to dump their waste. The greater the quantity of waste dumped into the river, the more the factories must pay. So again, the factories face the opportunity cost of the pollution they create. The quantity of chemical produced and the amount of waste dumped are the same whoever owns the homes and the river. If the factories own them, they bear the cost of pollution because they receive a lower income from home rents. If the residents own the homes and the river, the factories bear the cost of pollution because they must pay a fee to the homeowners. In both cases, the factories bear the cost of their pollution and dump the efficient amount of waste into the river.

The Coase solution works only when transactions costs are low. **Transactions costs** are the opportunity costs of conducting a transaction. For example, when you buy a house, you incur a series of transactions costs. You might pay a realtor to help you find the best place and a lawyer to run checks that assure you that the seller owns the property and that after you've paid for it, the ownership has been properly transferred to you.

In the example of the homes alongside a river, the transactions costs that are incurred by a small number of chemical factories and a few homeowners might be low enough to enable them to negotiate the deals that produce an efficient outcome. But in many situations, transactions costs are so high that it would be inefficient to incur them. In these situations, the Coase solution is not available.

Suppose, for example, that everyone owns the airspace above their homes up to, say, 10 miles. If someone pollutes your airspace, you can charge a fee. But to collect the fee, you must identify who is polluting your airspace and persuade them to pay you. Imagine the costs of negotiating and enforcing agreements with the 50 million people who live in your part of the United States (and perhaps in Canada or Mexico) and the several thousand factories that emit sulfur dioxide and create acid rain that falls on your property! In this situation, we use public choices to cope with external costs. But the transactions costs that block a market solution are real costs, so attempts by the government to deal with external costs offer no easy solution. Let's look at some of these attempts.

Government Actions in a Market with External Costs

The three main methods that governments use to cope with external costs are

- Taxes
- Emission charges
- Cap-and-trade

Taxes The government can use taxes as an incentive for producers to cut back the pollution they create. Taxes used in this way are called **Pigovian taxes**, in honor of Arthur Cecil Pigou, the British economist who first worked out this method of dealing with external costs during the 1920s.

By setting the tax equal to the marginal external cost, firms can be made to behave in the same way as they would if they bore the cost of the externality directly. To see how government actions can change the outcome in a market with external costs, let's return to the example of the chemical factories and the river.

Assume that the government has assessed the marginal external cost accurately and imposes a tax on the factories that exactly equals this cost. Figure 17.4 illustrates the effects of this tax.

The demand curve and marginal social benefit curve, *D* = *MSB*, and the firms' marginal cost curve, *MC*, are the same as in Fig. 17.2. The pollution tax equals the marginal external cost of the pollution. We add this tax to the marginal private cost to find the market supply curve. This curve is the one labeled *S* = *MC* + *tax* = *MSC*. This curve is the market supply curve because it tells us the quantity supplied at each price given the firms' marginal cost and the tax they must pay. This curve is also the marginal social cost curve because the pollution tax has been set equal to the marginal external cost.

Demand and supply now determine the market equilibrium price at $150 a ton and a quantity of

Economics in Action

The Greatest Market Failure?

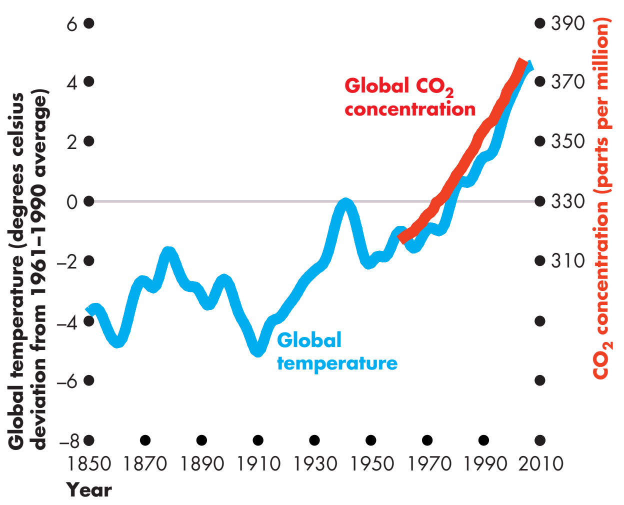
British economist Nicholas Stern reviewed the science and economics of global warming and climate change for the United Kingdom government and his report, the *Stern Review on the Economics of Climate Change* attracted much attention. Stern calls climate change "the greatest market failure the world has ever seen."

As the figure shows, global temperature and carbon dioxide (CO_2) trends are starkly upward. Stern says that to avoid the risk of catastrophic climate change, this upward trend must be stopped.

Scientists debate the contribution of human economic activity to these trends, but most say it is the major source. Although ice-core estimates show long swings in CO_2 concentration, the recent increase is the most rapid recorded.

The cost of achieving Stern's target is high, estimated at 1 percent of the value of global production. If this cost is to be met by the people who live in the rich countries, and realistically they are the only ones who can afford to pay, it will cost about $750 per person every year.

Some economists question Stern's assumptions and conclusions and argue that the cost of reducing emissions will be much lower if we go a bit more slowly and take advantage of future technological advances



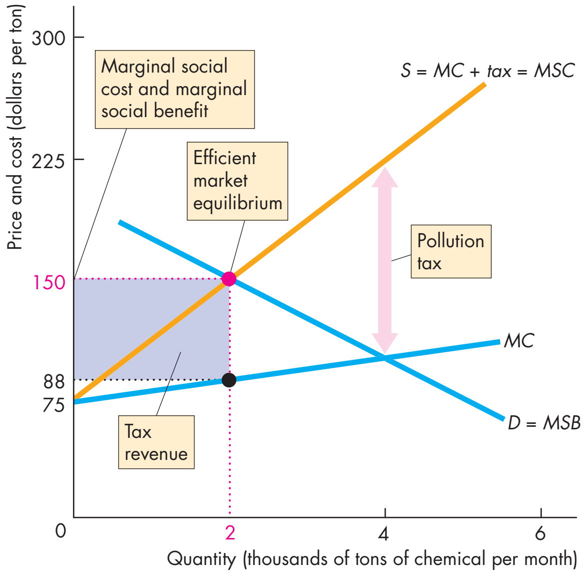
Global Warming Trends

Sources of data: Met Office Hadley Centre and Scripps Institution of Oceanography.

that will lower the cost of renewable energy sources—the sun, tide, and wind.

All economists agree that solving the global warming problem will require changes in the incentives that people face. The cost of carbon-emitting activities must rise and the cost of the search for new energy technologies must fall. A carbon tax or tradeable carbon permits are two possible ways of addressing this problem.

FIGURE 17.4 A Pollution Tax to Achieve an Efficient Outcome



When the government imposes a pollution tax equal to the marginal external cost of pollution, the supply curve becomes the marginal private cost curve, *MC*, plus the tax—the curve *S* = *MC* + *tax*. Market equilibrium occurs at a price of $150 a ton and a quantity of 2,000 tons of chemical a month. This equilibrium is efficient because marginal social cost equals marginal social benefit. The purple rectangle shows the government's tax revenue.

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2,000 tons of chemical a month. At this quantity of chemical production, the marginal social cost is $150 and the marginal social benefit is $150, so the outcome is efficient. The firms incur a marginal private cost of $88 a ton and pay a tax of $62 a ton. The government collects tax revenue of $124,000 a month.

Emission Charges Emission charges are an alternative to a tax for confronting a polluter with the external cost of pollution. The government sets a price per unit of pollution. The more pollution a firm creates, the more it pays in emission charges. This method of dealing with pollution externalities has been used only modestly in the United States but is common in Europe where, for example, France, Germany, and the Netherlands make water polluters pay a waste disposal charge.

To work out the emission charge that achieves efficiency, the government needs information about the polluting industry that, in practice, is rarely available.

Cap-and-Trade Instead of taxing or imposing emission charges on polluters, each potential polluter might be assigned a permitted pollution limit. Each firm knows its own costs and its benefits from pollution, and making pollution limits marketable is a clever way of using this private information that is unknown to the government. The government issues each firm a permit to emit a certain amount of pollution, and firms can trade these permits. Firms that have a low marginal cost of reducing pollution sell their permits, and firms that have a high marginal cost of reducing pollution buy permits. The market in permits determines the price at which firms trade permits. Each firm buys or sells permits until its marginal cost of pollution equals the market price of a permit.

This method of dealing with pollution provides an even stronger incentive than emission charges to find lower-polluting technologies because the price of a pollution permit rises as the demand for permits increases.

Trading in lead pollution permits became common during the 1980s, and this marketable permit program enabled lead pollution to be virtually eliminated in the United States (see p. 394). But this success might not easily translate to other pollutant because most lead pollution came from gasoline, which was easy to monitor.

REVIEW QUIZ

1. What is the distinction between private cost and social cost?
2. How do external costs prevent a competitive market from allocating resources efficiently?
3. How can external costs be eliminated by assigning property rights?
4. How do taxes help us to cope with external costs? At what level must a pollution tax be set to be efficient?
5. How do emission charges and marketable pollution permits work?

You can work these questions in Study Plan 17.1 and get instant feedback. myeconlab

Your next task is to study common resources and the government actions that can bring efficient use.

The Tragedy of the Commons

Overgrazing the pastures around a village in Middle Ages England, and overfishing the cod stocks of the North Atlantic Ocean during the recent past are tragedies of the commons. The **tragedy of the commons** is the overuse of a common resource that arises when its users have no incentive to conserve it and use it sustainably.

To study the tragedy of the commons and its possible remedies, we'll focus on the recent and current tragedy—overfishing and depleting the stock of Atlantic cod. We begin by thinking about the sustainable use of a renewable resource.

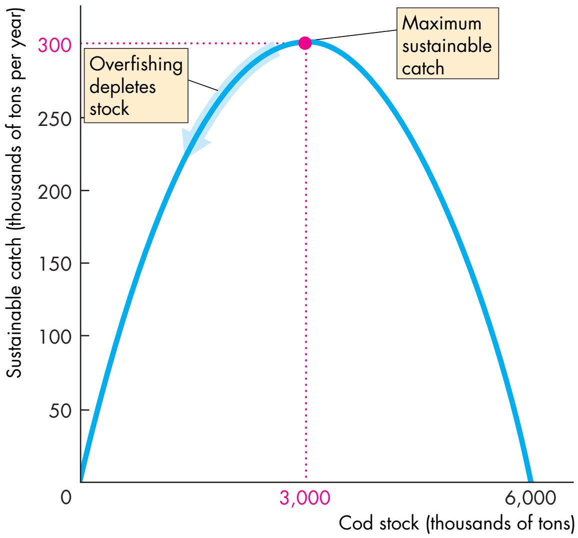
Sustainable Use of a Renewable Resource

A *renewable natural resource* is one that replenishes itself by the birth and growth of new members of the population. Fish, trees, and the fertile soil are all examples of this type of resource.

Focusing on fish, the sustainable catch is the quantity that can be caught year after year without depleting the stock. This quantity depends on the stock and in the interesting way illustrated in Fig. 17.6.

If the stock of fish is small, the quantity of new fish born is also small, so the sustainable catch is small.

FIGURE 17.5 Sustainable Catch



As the stock of fish increases (on the *x*-axis), the sustainable catch (on the *y*-axis) increases to a maximum. Beyond that number, more fish must compete for food and the sustainable catch falls.

If the catch exceeds the sustainable catch, the fish stock diminishes.

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Economics in Action

The Original Tragedy of the Commons

The term "tragedy of the commons" comes from fourteenth-century England, where areas of rough grassland surrounded villages. The commons were open to all and used for grazing cows and sheep owned by the villagers.

Because the commons were open to all, no one had an incentive to ensure that the land was not overgrazed. The result was a severe overgrazing situation. Because the commons were overgrazed, the quantity of cows and sheep that they could feed kept falling, the longer the overgrazing continued.

During the sixteenth century, the price of wool increased and England became a wool exporter to the world. Sheep farming became profitable, and sheep owners wanted to gain more effective control of the land they used. So the commons were gradually privatized and enclosed. Overgrazing ended, and land use became more efficient.

Economics in Action

One of Today's Tragedies of the Commons

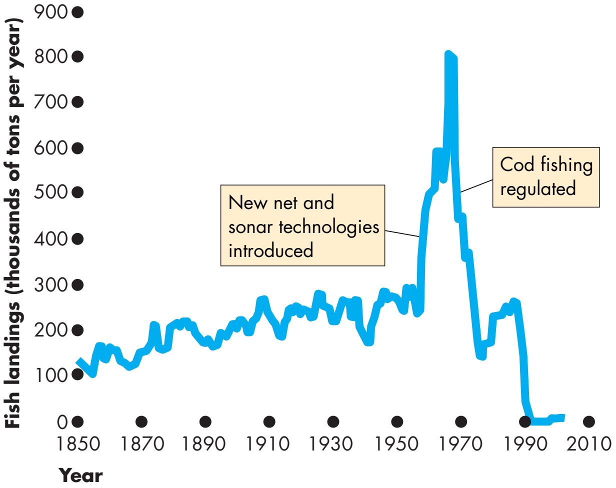
Before 1970, Atlantic cod was abundant. It was fished for many centuries and a major food source for the first European settlers in North America. During the sixteenth century, hundreds of European ships caught large quantities of cod in the northwest Atlantic off the coast of what is now New England and Newfoundland, Canada. By 1620, there were more than 1,000 fishing boats in the waters off Newfoundland, and in 1812 about 1,600 boats. During these years, cod were huge fish, typically weighing in at more than 220 pounds and measuring 3-6 feet in length.

Most of the fishing during these years was done using lines and productivity was low. But low productivity limited the catch and enabled cod to be caught sustainably over hundreds of years.

The situation changed dramatically during the 1960s with the introducton of high-efficiency nets (called trawls, seines, and gill nets), sonar technology to find fish concentrations, and large ships with efficient processing and storage facilities. These technological advances brought soaring cod harvests. In less than a decade, cod landings increased from less than 300,000 tons a year to 800,000 tons.

This volume of cod could not be taken without a serious collapse in the remaining stock and by the 1980s it became vital to regulate cod fishing. But regulation was of limited success and stocks continued to fall.

In 1992, a total ban on cod fishing in the North Atlantic stabilized the population but at a very low level. Two decades of ban have enabled the species to repopulate, and it is now hoped that one day cod fishing will return but at a low and sustainable rate.



The Atlantic Cod Catch: 1850–2005

Source of data for graph: Millenium Ecosystem Assessment.
Source of information: Codfishes—Atlantic cod and its fishery, http://science.jrank.org/

If the fish stock is large, many fish are born, but they must compete with each other for food so only a small number survive to reproduce and to grow large enough to catch.

Between a small and a large stock is a quantity of fish stock that maximizes the sustainable catch. In Fig. 17.5, this fish stock is 3,000 thousand tons and the sustainable catch is 300 thousand tons a year. The maximum sustainable catch arises from a balancing of the birth of new fish from the stock and the availability of food to sustain the fish popuation.

If the quantity of fish caught is less than the sustainable catch, the fish stock grows; if the quantity caught exceeds the sustainable catch, the fish stock shrinks; and if the quantity caught equals the sustainable catch, the fish stock remains constant and is available for future generations of fishers in the same quantity that is available today.

If the fish stock exceeds the level that maximizes the sustainable catch, overfishing isn't a problem. But if the fish stock is less than the level that maximizes the sustainable catch, overfishing depletes the stock.