William A. McEachern (2018). ECON MICRO (6th ed.). Cengage Learning. ISBN: 978-1-337-408066.

- Why do people fish until the fish are gone?
- Why might environmentalists buy pollution rights to the air and water?
- How did barbed wire tame the Wild West?
- How might a lack of property rights contribute to climate change?
- What is the optimal level of pollution?
- And how does someone else's antitheft device affect the chances that your car will get stolen?

These and other questions are answered in this chapter, which looks at externalities and the environment.

The rivers in Jakarta, Indonesia, are dead—killed by acid, alcohol, and oil. Coral reefs in the South Pacific are being ripped apart by dynamite fishing. The air in New Delhi, India, is more toxic than the air in any other city on earth, with 15 times the pollution level considered safe by the World Health Organization. The tropical rainforest is shrinking because of slash and-burn claims on the land's resources. The build-up of greenhouse gases threatens to warm the oceans and near-surface air. Some streams in Colorado are still considered toxic from gold mining that ended more than a century ago. These environmental problems are all negative externalities, which result from the actions of producers or consumers that affect many others. Markets can allocate resources efficiently only as long as property rights are well defined and can be easily enforced. But property rights to clean water, air, and soil, to fish in the ocean, to peace and quiet, and to scenic vistas are hard to establish and enforce. This lack of property rights to some resources results in externalities.

Externalities may be either negative, such as air and water pollution, or positive, such as the general improvement in the civic climate that results from better education. This chapter explores how public policies can reduce negative externalities and increase positive externalities.

> "What is the optimal level of pollution?"

17-1 EXTERNALITIES AND THE COMMON-POOL PROBLEM

Let's begin by distinguishing between exhaustible resources and renewable resources. An **exhaustible resource** such as oil or coal does not renew itself and so is available in a finite amount. Technology may improve the ability to extract and utilize these resources, but each gallon of oil burned is gone forever. Sooner or later, all accessible oil and coal deposits will be gone. The world's oil and coal reserves are *exhaustible*.

17-1a Renewable Resources

A resource is renewable if, when used conservatively, it can be drawn on indefinitely. Thus, timber is a **renewable resource** if trees are cut at sustainable rates and replaced with seedlings. The atmosphere and rivers are renewable resources to the extent that they can absorb and neutralize a certain level of pollutants. More generally, biological resources like fish, game, forests, rivers, grasslands, and agricultural soil are renewable if managed appropriately.

Some renewable resources are also open-access resources, an idea introduced in Chapter 16. An open-access resource is rival in consumption, but exclusion is costly. Fish caught in the ocean, for example, are not available for others to catch, so fish are rival in consumption. Yet it would be difficult, if not impossible, for a person or a firm to "own" fish still swimming in open waters and to prevent others

exhaustible resource
A resource in fixed supply, such as crude oil or coal

renewable resource
A resource that regenerates itself and so can be used indefinitely if used conservatively, such as a well-managed forest

Michima Photography/Getty Images

When harvested responsibly, timber is an indefinitely renewable resource.

from catching them, so ocean fish are nonexclusive. An open-access good is often subject to the **common-pool problem**, which results because people harvest a resource as long as the marginal benefit exceeds marginal cost. For example, people will fish the oceans as long as the marginal benefit of catching more fish exceeds the marginal cost. Individual fishing parties have little regard for the effects of their catch on the sustainability of fishing stocks. Practically speaking, unless otherwise checked, people will fish until the oceans become "fished out." Open-access goods are overfished, overhunted, over-harvested, and overused. Because the atmosphere is an open-access resource, it's used as a dump for unwanted gases. Air pollution is a negative externality imposed on society by polluters. The problem is that people exploit any resource as long as their personal marginal benefit exceeds their personal marginal cost. As we'll see, personal marginal cost ignores the costs imposed on others.

In a market system, specific individuals usually own the rights to resources and therefore have a strong interest in using those resources efficiently. *Private property rights*, a term introduced in Chapter 2, allow individuals to use resources or to charge others for their use. Private property rights are defined and enforced by government, by informal social actions, and by ethical norms. As Robert Frost wrote, "Good fences make good neighbors."[1] Assets such as fishing rights are more valuable when they are more enforceable.[2] But because defining and enforcing property rights to open-access resources, such as the air, are quite costly if not impossible, these resources usually are not owned as private property.

Pollution and other negative externalities arise because there are no practical, enforceable, private property rights to open-access resources, such as the air. Market prices usually fail to include the costs that negative externalities impose on society. For example, the price you pay for a gallon of gasoline does not reflect the costs imposed by the greenhouse gases, sootier air, oil spills, and greater congestion and accidents your driving creates. Electric rates do not reflect the negative externalities, or external costs, caused by fossil-fueled power plants. Note that externalities are unintended side effects of actions that are themselves useful and purposeful. Electricity producers, for example, did not go into business to pollute.

17-1b Resolving the Common-Pool Problem

Users of the atmosphere, waterways, wildlife, or other open-access resources tend to ignore the impact of their use on the resource's renewal ability. As quality and quantity diminish from overuse, the resource grows scarcer and could disappear. For example, Georges Bank, located off the New England coast, and long one of the world's most productive fishing grounds, became so depleted by overfishing that by the 1990s the catch was down 85 percent from peak years. Tuna, once abundant in the Mediterranean, now faces extinction there. The United Nations reports that at least 11 of the world's 15 primary fishing grounds are seriously depleted.

By imposing restrictions on resource use, government regulations may reduce the common-pool problem. Output restrictions or taxes could force people to use the resource at a rate that is socially optimal, a rate that supports a sustainable yield. For example, in the face of the tendency to overfish and to catch fish before they are sufficiently mature, the U.S. government has imposed a number of restrictions on the fishing industry. The laws limit the total catch, the size of fish, the length of the fishing season, the equipment used, and other aspects of the business.

More generally, when imposing and enforcing private property rights would be too costly, government regulations may improve allocative efficiency. For example, stop signs and traffic lights allocate the scarce space at intersections, minimum size restrictions control lobster fishing, hunting seasons control the stock of game, and enforced study hours may calm the din in the college dormitory.

common-pool problem Unrestricted access to a renewable resource results in overuse

1. From the poem "Mending Wall" in Robert Frost, *You Come Too* (Holt, Rinehart and Winston, 1967), p. 64.

2. Corbett Grainger and Christopher Costello, "Capitalizing Property Rights Insecurity in Natural Resource Assets," *Journal of Environmental Economics and Management*, 47 (March 2014): 224–240.

"UNINTENDED CONSEQUENCES IN ICELAND"

As can be seen in this description of the responses to Icelandic fishing regulations, unintended consequences of such regulations can lead to inefficiency:

> *The Icelandic government realized that it would have to curb the capacity of its own fleet. But the fishermen compensated by buying more trawlers. Then the government restricted the size of the fleet and the number of days at sea; the fishermen responded by buying larger, more efficient gear. The cod stocks continued to decline. In 1984, the government introduced quotas on species per vessel per season. This was a controversial and often wasteful system. A groundfish hauled up from 50 fathoms [300 feet] is killed by the change in pressure. But if it is a cod and the cod quota has been used up, it is thrown overboard. Or if the price of cod is low that week and cod happens to come in the haddock net, the fishermen will throw them overboard because they do not want to use up their cod quota when they are not getting a good price.**

* Mark Kurlansky, *Cod: A Biography of the Fish That Changed the World* (Walker, 1997), p. 172.

But not all regulations are equally efficient. For example, fishing authorities sometimes limit the total industry catch and allow all firms to fish until that limit is reached. Consequently, when the fishing season opens, there is a mad scramble to catch as much as possible before the industry limit is reached. Because time is of the essence, fishing boats make no effort to fish selectively. And the catch reaches processing plants all at once, creating congestion throughout the supply chain. Also, each firm has an incentive to expand its fishing fleet to catch more in those precious few weeks. Thus, large fleets of technologically efficient fishing vessels operate for a few weeks until the limit is reached and then sit in port for the rest of the year. Each operator is acting rationally, but the collective effect of the regulation is grossly inefficient in terms of social welfare.

Ocean fish remain a common-pool resource because firms have not yet been able to establish and enforce rights to particular schools of fish. But advances in technology may one day allow the creation of private property rights to ocean fish, migrating birds, and other open-access resources. Establishing property rights to cattle on the Great Plains once seemed impossible, but the invention of barbed wire allowed ranchers to fence the range. Patented in 1867, barbed wire was advertised as "The finest fence in the world. Light as air. Stronger than whiskey. Cheaper than dirt." In a sense, barbed wire, by reducing the cost of fencing the open range, tamed the Wild West.[3]

3. Richard Hornbeck, "Barbed Wire: Property Rights and Agricultural Development," *Quarterly Journal of Economics*, 125 (May 2010): 767–810.

> "The price you pay for a gallon of gasoline does not reflect the costs imposed by the greenhouse gases, sootier air, oil spills, and greater congestion and accidents your driving creates."

17-2 OPTIMAL LEVEL OF POLLUTION

Though the science is not yet fully resolved, fossil fuel used to power the likes of automobiles and electricity generators produces carbon dioxide, which mixes with other greenhouse gases that could contribute to climate change. Electricity production from fossil fuels, therefore, involves the external cost of using the atmosphere as a gas dump. This section considers a way to analyze such externalities.

17-2a External Costs with Fixed Technology

Suppose *D* in Exhibit 17.1 depicts the demand for electricity. Recall that a demand curve reflects consumers' marginal benefit of each unit. The lower horizontal line reflects the marginal private cost of generating electricity using fossil fuels. If producers base their pricing and output decisions on their marginal private costs, the equilibrium quantity per month is 50 million kilowatt-hours and the equilibrium price is $0.10 per kilowatt-hour. At that price and quantity, identified by point *a*, the marginal private cost of production just equals the marginal benefit enjoyed by consumers of electricity.

Electricity production involves not only the private cost of the resources employed but also the external cost of using the atmosphere as a dump for greenhouse gases. Suppose that the marginal external cost imposed on the environment by the generation of electricity is $0.04 per kilowatt-hour. If the only way to cut emissions is to reduce electricity production, then the relationship between electricity production and pollution is fixed; the pollution in this case occurs with **fixed-production technology**.

The vertical distance between the marginal private cost curve and the marginal social cost curve in Exhibit 17.1 shows the marginal external cost of $0.04 per kilowatt-hour. The **marginal social cost** includes both the marginal private cost and the marginal

fixed-production technology Occurs when the relationship between the output rate and the generation of an externality is fixed; the only way to reduce the externality is to reduce the output

marginal social cost The sum of the marginal private cost and the marginal external cost of production or consumption

iStockphoto.com/Trevor Fisher

Electricity production almost always results in an external cost of some sort.

external cost that production imposes on society. Because the marginal external cost here is assumed to be a constant $0.04 per kilowatt-hour, the two cost curves are parallel. Notice that at the private-sector equilibrium output level of 50 million kilowatt-hours, the marginal social cost, identified at point *b*, exceeds society's marginal benefit of electricity, identified on the demand curve at point *a*. The 50-millionth kilowatt-hour of electricity costs society $0.14 but yields only $0.10 of marginal benefit. Because the marginal social cost exceeds the marginal benefit, too much electricity is produced.

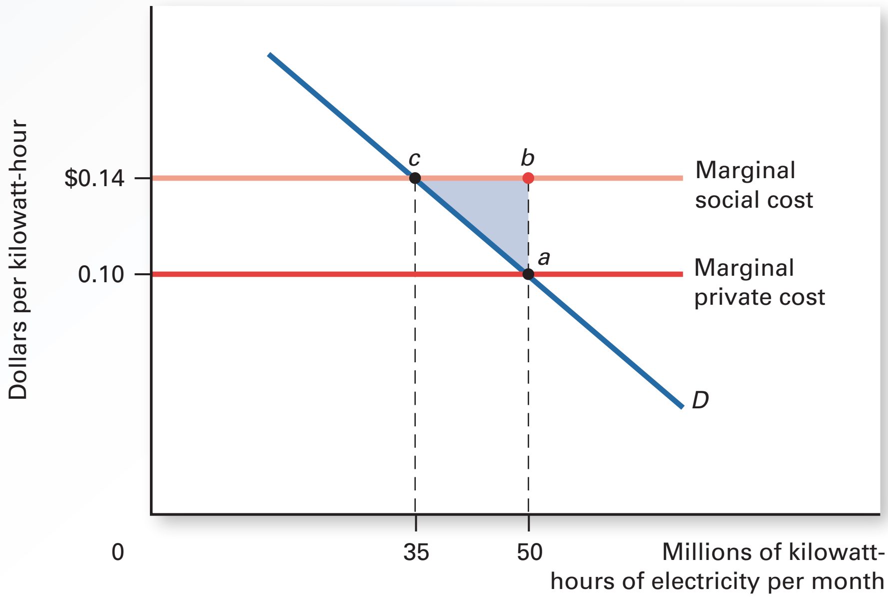
The efficient quantity of 35 million kilowatt-hours is found where the demand, or marginal benefit, curve intersects the marginal social cost curve. This intersection is identified at point *c*. How could output be restricted to the socially efficient amount? If regulators knew the demand and marginal cost curves, they could simply limit production to 35 million kilowatt-hours, the efficient quantity. Or, on each kilowatt-hour produced, they could impose a tax equal to the marginal external cost of $0.04. Such a pollution tax would lift the marginal private cost curve up to the marginal social cost curve. Thus, the tax would bring private costs in line with social costs.

With a tax of $0.04 per kilowatt-hour, the equilibrium combination of price and output moves from point *a* to point *c*. The price rises from $0.10 to $0.14 per kilowatt-hour, and output falls to 35 million kilowatt-hours. Setting the tax equal to the marginal external cost results in the efficient level of output. At point *c*, the marginal social cost of production equals the marginal benefit. Notice that greenhouse gas emissions are not eliminated at point *c*, but the utilities no longer generate electricity for which marginal social cost exceeds marginal benefit. The social gain from reducing production to the socially optimal level is shown by the blue-shaded triangle in Exhibit 17.1. This triangle also measures the social cost of allowing firms to ignore the external cost of their production. Although Exhibit 17.1 offers a tidy solution, the external costs of greenhouse gases often cannot be easily calculated or taxed. At times, government intervention may result in more or less production than the optimal solution requires.

Exhibit 17.1

Negative Externalities: The Market for Electricity in the Midwest

If producers base their output on marginal private cost, 50 million kilowatt-hours of electricity are produced per month. The marginal external cost of electricity is the cost of pollution imposed on society. The marginal social cost curve includes both the marginal private cost and the marginal external cost. If producers base their output decisions on marginal social cost, only 35 million kilowatt-hours are produced, which is the optimal output. The total social gain from basing production on marginal social cost is reflected by the blue-shaded triangle.



17-2b External Costs with Variable Technology

The previous example assumes that the only way to reduce greenhouse gases is to reduce output. But power companies, particularly in the long run, can usually change their resource mix to reduce emissions for any given rate of electricity output. If pollution can be reduced by altering the production process rather than by simply adjusting the quantity, these externalities are said to be produced under conditions of **variable technology**. For example, between 1990 and 2008 the real value of U.S. manufacturing output grew by more than one-third. But, thanks to better emission technology, pollution from U.S. factories fell by two-thirds.[4] *With variable technology, the idea is to find the most efficient level of pollution for a given rate of output*.

Let's look at Exhibit 17.2. The horizontal axis measures greenhouse gas emissions for a given rate of electricity production. Emissions can be reduced by adopting cleaner production technology. Yet the production of cleaner air, like the production of other goods, is subject to diminishing returns. Cutting emissions of the most offensive greenhouse gases may involve simply changing the fuel mix, but further reductions could require more sophisticated and more expensive processes. Thus, the marginal social cost of reducing greenhouse gases increases, as shown by the upward-sloping marginal social cost curve in Exhibit 17.2.

The **marginal social benefit** curve reflects the additional benefit society derives from greenhouse gas reductions. When emissions are high, any improvement can save lives and thus is valued by society more than when emissions are low. Cleaner air, like other goods, has a declining marginal benefit to society (though the total benefit still increases). The marginal social benefit curve from cleaner air therefore slopes downward, as shown in Exhibit 17.2.

"The optimal level of air quality for a given rate of electricity production is found where the marginal social benefit of cleaner air equals the marginal social cost."

The optimal level of air quality for a given rate of electricity production is found at point *a*, where the marginal social benefit of cleaner air equals the marginal social cost. In this example, the optimal level of greenhouse gas emissions is *A*. If firms made their production decisions based simply on their private cost—that is, if the emission cost is external to the firm—then firms would have little incentive to search for production methods that reduce greenhouse gas emission, so too much pollution would result.

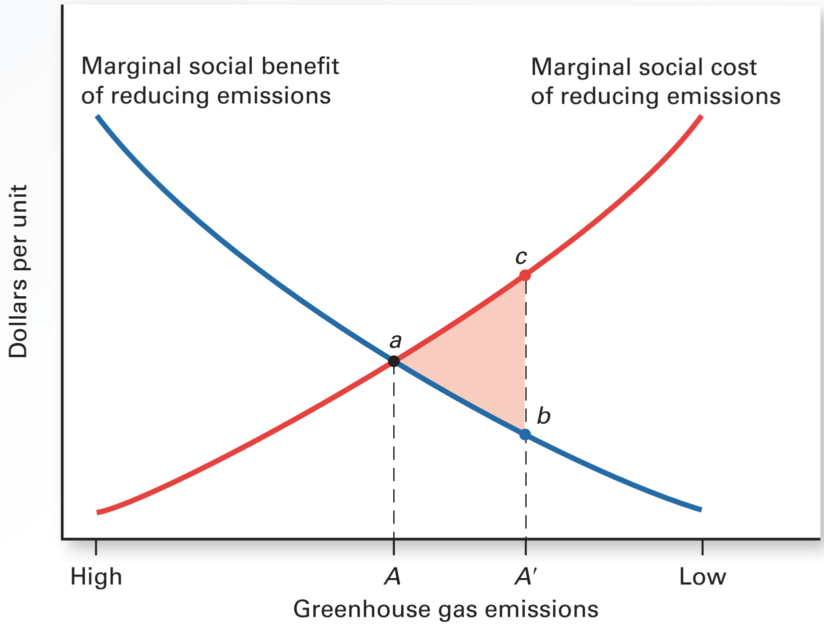
variable technology Occurs when the amount of externality generated at a given rate of output can be reduced by altering the production process

marginal social benefit The sum of the marginal private benefit and the marginal external benefit of production or consumption

Exhibit 17.2

The Optimal Reduction in Greenhouse Gas Emissions

The optimal level of greenhouse gas emissions for a given rate of output is found at point *a*, where the marginal social benefit of reducing such emissions equals the marginal social cost. If some lower level of emissions were dictated by the government, such as *A′*, the marginal social cost would exceed the marginal social benefit, and social waste would result. The total social waste resulting from a lower than optimal level of emissions is shown by the pink-shaded triangle.



4. Arik Levinson, "A Direct Estimate of the Technique Effect: Changes in Pollution Intensity of U.S. Manufacturing 1990–2008," *Journal of the Association of Environmental and Resource Economists*, 2 (June 2015): 43–56.

What if government regulators decree that greenhouse gas emission levels should be no greater than *A′*? For example, suppose a law establishes *A′* as the maximum acceptable level of emissions. The marginal social cost, identified as *c*, of achieving that level of air quality exceeds the marginal social benefit, identified as *b*. The total social waste associated with imposing a greater-than-optimal level of air quality is shown by the pink-shaded triangle, *abc*. This area is the total amount by which the additional social costs of cleaner air (associated with a move from *A* to *A′*) exceed the additional social benefits. Improving air quality benefits society only as long as the marginal social benefit of cleaner air exceeds its marginal social cost.

What would happen to the optimal level of emissions if either the marginal cost curve or the marginal benefit curve shifted? For example, suppose some technological breakthrough reduces the marginal cost of cut ting greenhouse gas emissions. As shown in panel (a) of Exhibit 17.3, the marginal social cost curve of reducing emissions would shift downward to *MSC′*, leading to cleaner air as reflected by the movement from *A* to *A′*. *The simple logic is that the lower the marginal cost of reducing greenhouse gases, other things constant, the cleaner the optimal level of air quality*.

An increase in the marginal benefit of air quality (or more accurately, a better understanding of the benefit of air quality) has a similar effect. For example, new scientific findings showing the effects of cleaner air on health or the climate may increase the perceived benefits from improved air quality. Thus, the marginal benefit of cleaner air increases, as reflected in panel (b) of Exhibit 17.3 by an upward shift of the marginal social benefit curve to *MSB′*. As a result, optimal air quality would improve, moving from *A* to *A″* in panel (b) of Exhibit 17.3. *The greater the marginal benefit of reducing greenhouse gases, other things constant, the cleaner the optimal level of air quality*.

17-2c The Coase Theorem

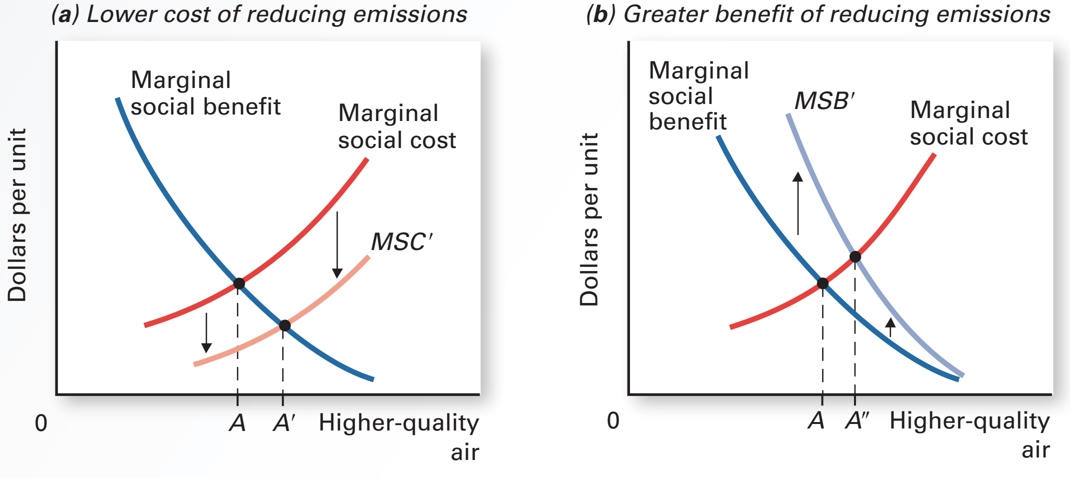
The traditional analysis of externalities assumes that market failures arise because people ignore the external effects of their actions. For example, suppose that a manufacturer of heavy machinery is next door to a research laboratory that tests delicate measuring equipment. The vibrations caused by the manufacturing process throw off the delicate equipment next door. Professor Ronald Coase, who won the Nobel Prize in 1991, would argue that the negative externality in this case is not necessarily imposed by the heavy machinery—rather, it arises from the incompatible activities of the two firms. The externality is the result of both vibrations created by the factory *and* the location of the testing lab next door. Solutions might include modifying the factory, moving the factory, making the test equipment more shock resistant, or moving the testing lab.

According to Coase, the efficient solution depends on which party can avoid the externality at the lower cost. Suppose it would cost $2 million for the factory

Exhibit 17.3

Effect of Changes in Costs or Benefits of Reducing Greenhouse Gas Emissions

Either a reduction in the marginal social cost of cleaner air, as shown in panel (a), or an increase in the marginal social benefit of cleaner air, as shown in panel (b), increases the optimal level of air quality.



According to EPA estimates, compliance with pollution-control regulations cost U.S. producers and consumers more than $300 billion in 2015. We can divide pollution control spending into three categories: for air pollution abatement, for water pollution abatement, and for solid waste disposal. About 40 percent of the pollution control expenditures in the United States goes toward cleaner air, another 40 percent goes toward cleaner water, and 20 percent goes toward disposing of solid waste. In this section, we consider, in turn, air pollution, water pollution, Superfund activities, and disposing of solid waste.

17-3a Air Pollution

Among the many harmful effects of air pollution is the impairment of fetal development as reflected later in life by lower math and language skills.[7] In the Clean Air Act of 1970 and in subsequent amendments, Congress set national standards for the amount of pollution that could be released into the atmosphere. Congress thereby recognized the atmosphere as an economic resource, which, like other resources, has alternative uses. The air can be used as a source of life-giving oxygen, as a prism for viewing breathtaking vistas, or as a dump for carrying away unwanted soot and gases. The 1970 act gave Americans the right to breathe air of a certain quality and at the same time gave producers the right to emit certain amounts of specified pollutants. But there is no free lunch: the Clean Air Act imposes an estimated annual cost of about $25 billion. What's more, many firms respond to regulatory pressure by cutting their workforce, so some people lose jobs.[8] Still, research shows that people value clean air, and we are still discovering additional benefits. For example, there is now evidence that reductions in auto emissions reduce child mortality.[9] Throughout the world, people are willing to pay more to live where there is less pollution.[10] For example, surveys show that many people in China who become rich soon migrate to countries with cleaner air and bluer skies.[11]

Smog is the most visible form of air pollution. Automobile emissions account for 40 percent of smog. Another 40 percent comes from consumer-oriented products, such as paint thinner, fluorocarbon sprays, dry-cleaning solvents, and baker's yeast by-products. Surprisingly, only 15 percent of smog comes from manufacturing. The 1970 Clean Air Act mandated a reduction of 90 percent in auto emissions, leaving it to the auto industry to achieve this target. At the time, automakers said the target was impossible. Between 1970 and 1990, however, average emissions of lead fell 97 percent, carbon monoxide emissions fell 41 percent, and sulfur dioxide emissions fell 25 percent. In fact, an EPA study concluded that because auto emissions and industrial smoke have been reduced so much, *air pollution on average is now lower outdoors than indoors*. U.S. air quality is now considered good compared to the air quality in much of the world. For example, no U.S. city ranks among the world's worst in sulfur dioxide. Despite recent improvements in air quality, the United States is still a major source of fossil-fuel carbon dioxide emissions, a greenhouse gas. As you can see from Exhibit 17.5, which shows the world's 25 worst nations in annual fossil-fuel carbon dioxide emissions per capita, the United States ranks tenth worst with 16.1 tons of carbon per capita (down 22 percent from the year 2000). Overall, the United States is the second largest emitter of carbon dioxide, accounting for 14 percent of the global total. China is the largest emitter and is responsible for 29 percent of global carbon dioxide emissions.

"Air pollution on average is now lower outdoors than indoors."

Jaroslav Moravcik/Shutterstock.com

While this is normally what we think of when we think of air pollution, in actuality only about 15 percent of air pollution results from manufacturing. Most comes from automobiles and consumer products.

7. Prashant Bharadwaj et al., "Gray Matters: Fetal Pollution Exposure and Human Capital Formation," NBER Working Paper No. 20662 (November 2014).

8. W. Reed Walker, "Environmental Regulation and Labor Reallocation: Evidence from the Clean Air Act," *American Economic Review*, 101 (May 2011): 442.

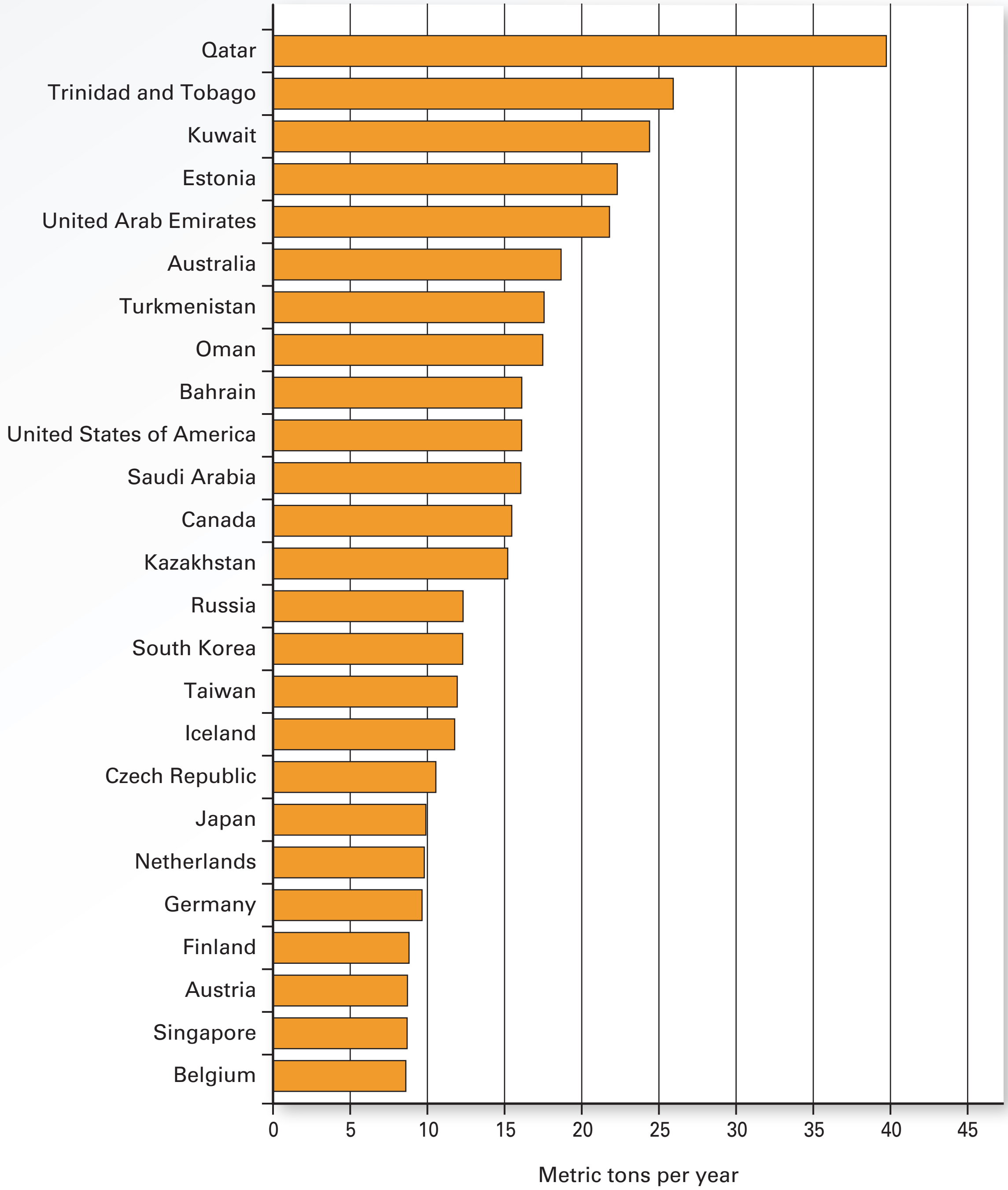
9. Christopher Knittel, Douglas Miller, and Nicholas Sanders, "Caution, Drivers! Children Present: Traffic, Pollution, and Infant Health," *Review of Economics and Statistics*, 98 (May 2016): 350–366.

10. Kenneth Chay and Michael Greenstone, "Does Air Quality Matter? Evidence from the Housing Market," *Journal of Political Economy*, 113 (April 2005): 376–424.

11. Andrew Browne, "The Great China Exodus," *Wall Street Journal*, 26 September 2014.

Exhibit 17.5

Fossil-Fuel Carbon Dioxide Emissions per Capita: The 25 Worst Nations



Source: Emissions Database for Global Atmospheric Research (EDGAR), "CO2 Time Series 1990–2015 per Capita for World Countries" at https://edgar.jrc.ec.europa.eu/overview.php?v=CO2ts_pc1990-2015&sort=des9. Excluded are nations with fewer than one million people.

There have been efforts to address greenhouse gases on an international scale. Most notably, the Paris Agreement is a United Nations-brokered agreement that is intended to reduce hazardous emissions worldwide and slow global warming. It was signed by 194 countries and the European Union. As of July 2017, it has been ratified by 153 of those parties. Currently the United States, under President Trump, is set to withdraw from the agreement though several states have promised that they will still abide by the agreement.