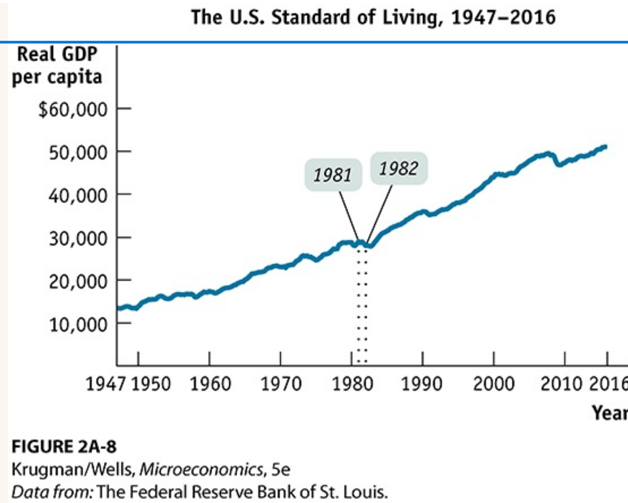
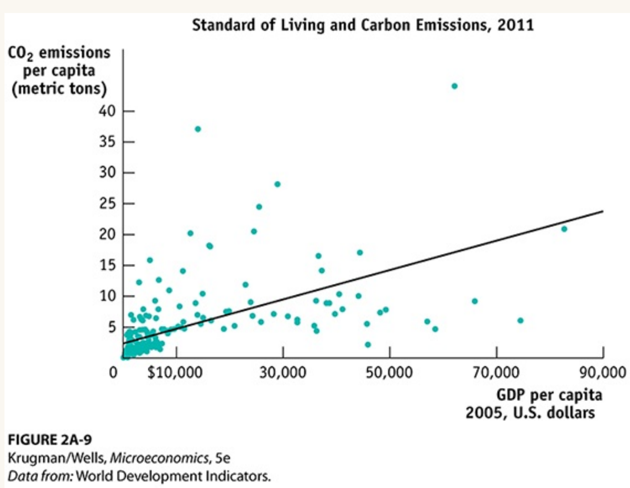
Paul Krugman, Robin Wells (2018). Microeconomics (5th ed.). Worth Publishers. ISBN: 978-1-319-098780.
Pages: 196-197, 443-444, 495-496, 1031-1032,1036-1038, 1043-1046, 1064, 1259, 1386.



Time-series graphs show successive dates on the x-axis and values for a variable on the y-axis. This time-series graph shows real gross domestic product per capita, a measure of a country's standard of living, in the United States from 1947 to early 2016.

Figure 2A-9 is an example of a different kind of numerical graph. It represents information from a sample of 186 countries on the standard of living, again measured by GDP per capita, and the amount of carbon emissions per capita, a measure of environmental pollution. Each point here indicates an average resident's standard of living and his or her annual carbon emissions for a given country.

FIGURE 2A-9 Scatter Diagram



In a scatter diagram, each point represents the corresponding values of the x- and y-variables for a given observation. Here, each point indicates the GDP per capita and the amount of carbon emissions per capita for a given country for a sample of 186 countries. The upward-sloping fitted line here is the best approximation of the general relationship between the two variables.

The points lying in the upper right of the graph, which show combinations of a high standard of living and high carbon emissions, represent economically advanced countries such as the United States. (The country with the highest carbon emissions, at the top of the graph, is Qatar.) Points lying in the bottom left of the graph, which show combinations of a low standard of living and low carbon emissions, represent economically less advanced countries such as Afghanistan and Sierra Leone.

The pattern of points indicates that there is a positive relationship between living standard and carbon emissions per capita: on the whole, people create more pollution in countries with a higher standard of living.

This type of graph is called a **scatter diagram**, in which each point corresponds to an actual observation of the *x*-variable and the *y*-variable. In scatter diagrams, a curve is typically fitted to the scatter of points; that is, a curve is drawn that approximates as closely as possible the general relationship between the variables. As you can see, the fitted line in Figure 2A-9 is upward sloping, indicating the underlying positive relationship between the two variables. Scatter diagrams are often used to show how a general relationship can be inferred from a set of data.

A **scatter diagram** shows points that correspond to actual observations of the *x*- and *y*-variables. A curve is usually fitted to the scatter of points.

A **pie chart** shows the share of a total amount that is accounted for by various components, usually expressed in percentages. For example, Figure 2A-10 is a pie chart that depicts the education levels of workers who in 2015 were paid the federal minimum wage or less. As you can see, the majority of workers paid at or below the minimum wage had no college degree. Only 19% of workers who were paid at or below the minimum wage had a bachelor’s degree or higher.

A **pie chart** shows how some total is divided among its components, usually expressed in percentages.

among drug users. Opponents believe that doing so will encourage more drug use by reducing the risks of this behavior. As an economist asked to assess the policy, you must know the following: (i) how responsive the spread of diseases like HIV/AIDS is to the price of sterile needles and (ii) how responsive drug use is to the price of sterile needles. Assuming that you know these two things, use the concepts of price elasticity of demand for sterile needles and the cross-price elasticity between drugs and sterile needles to answer the following questions.

a. In what circumstances do you believe this is a beneficial policy?
b. In what circumstances do you believe this is a bad policy?

. Worldwide, the average coffee grower has increased the amount of acreage under cultivation over the past few years. The result has been that the average coffee plantation produces significantly more coffee than it did 10 to 20 years ago. Unfortunately for the growers, however, this has also been a period in which their total revenues have plunged. In terms of an elasticity, what must be true for these events to have occurred? Illustrate these events with a diagram, indicating the quantity effect and the price effect that gave rise to these events.

. A 2015 article published by the *American Journal of Preventive Medicine* studied the effects of an increase in alcohol prices on the incidence of new cases of sexually transmitted diseases. In particular, the researchers studied the effects that a Maryland policy increasing alcohol taxes had on the decline in gonorrhea cases. The report concluded that an increase in the alcohol tax rate by 3% resulted in 1,600 fewer cases of gonorrhea. Assume that prior to the tax increase, the number of gonorrhea cases was 7,450. Use the midpoint method to determine the percent decrease in gonorrhea cases, and then calculate the cross-price elasticity of demand between alcohol and the incidence of gonorrhea. According to your estimate of this cross-price elasticity of demand, are alcohol and gonorrhea complements or substitutes?

. The U.S. government is considering reducing the amount of carbon dioxide that firms are allowed to produce by issuing a limited number of tradable allowances for carbon dioxide (CO_2) emissions. In a recent report, the U.S. Congressional Budget Office (CBO) argues that “most of the cost of meeting a cap on CO_2 emissions would be borne by consumers, who would face persistently higher prices for products such as electricity and gasoline . . . poorer households would bear a larger burden relative to their income than wealthier households would." What assumption about one of the elasticities you learned about in this chapter has to be true for poorer households to be disproportionately affected?

. According to data from the U.S. Department of Energy, sales of the fuel-efficient Toyota Prius hybrid fell from 194,108 vehicles sold in 2014 to 180,603 in 2015. Over the same period, according to data from the U.S. Energy Information Administration, the average price of regular gasoline fell from $3.36 to $2.43 per gallon. Using the midpoint method, calculate the cross-price elasticity of demand between Toyota Prii (the official plural of "Prius" is "Prii") and regular gasoline. According to your estimate of the cross-price elasticity, are the two goods complements or substitutes? Does your answer make sense?

WORK IT OUT

17. Nile.com, the online bookseller, wants to increase its total revenue. One strategy is to offer a 10% discount on every book it sells. Nile.com knows that its customers can be divided into two distinct groups according to their likely responses to the discount. The accompanying table shows how the two groups respond to the discount.

	Group A (sales per week)	Group B (sales per week)
Volume of sales before the 10% discount	1.55 million	1.50 million
Volume of sales after the 10% discount	1.65 million	1.70 million

a. Using the midpoint method, calculate the price elasticities of demand for group A and group B.
b. Explain how the discount will affect total revenue from each group.
c. Suppose Nile.com knows which group each customer belongs to when he or she logs on and can choose whether or not to offer the 10% discount. If Nile.com wants to increase its total revenue, should discounts be offered to group A or to group B, to neither group, or to both groups?

Jefri Tarigan /Anadolu Agency/Getty Images

Microsoft's various business units—such as its Intelligent Cloud Division—are assessed on their performance by senior management each quarter (every three months). One of the major factors in the performance review is quarterly profit—that is, how much did the business unit earn over and above its costs. So it might be surprising to learn that one type of cost that Microsoft's business units must pay is a tax—a carbon tax—that is levied internally by Microsoft on its own units. In fact, in 2015 Microsoft was one of 437 companies that levied an internal carbon tax on its business units. Other companies included Google, Disney, and ExxonMobil.

A *carbon tax* is a tax on a good or service assessed according to the amount of carbon dioxide created by the production of that good or service. Carbon dioxide is one of the main pollutants behind global climate change.

A Microsoft business unit determines its carbon tax levy by calculating the total amount of energy that it consumes for its operations—such as the energy consumed for its office space, data centers, or business travel. Next, the amount of energy consumed is converted into metric tons of carbon—the amount of carbon emissions generated by the unit's consumption of energy. Microsoft's Environmental Sustainability Team then calculates each unit's carbon tax. In 2015, Microsoft collected approximately $20 million in carbon tax revenue from its business units.

Finally, the carbon tax revenue is placed in a fund that pays for a range of clean energy projects within Microsoft. For example, at its corporate headquarters in Redmond, Washington, carbon tax revenue paid for a data collection and software system that optimized energy use across 125 buildings, leading to huge cost and carbon-emissions savings. In its first three years, the carbon tax system has led to a $10 million savings for Microsoft through reduced energy consumption and a 7.5 million metric ton reduction in carbon emissions.

Although the internal carbon tax scheme reduces the company's profit in the short run, Microsoft's shareholders support the scheme. They believe that reducing energy consumption in the long run will lead to higher future profits. Furthermore, some observers believe that internal carbon taxes put companies adopting them a step ahead as global climate change increases the likelihood that governments will adopt policies to reduce carbon emissions.

QUESTIONS FOR THOUGHT

To save energy and reduce carbon emissions, why do you think that Microsoft instituted a tax rather than issue a company-wide directive?

How is Microsoft behaving like a government? Why is this preferable to business units acting independently?

What is a possible downside to the internal carbon tax scheme? What trade-offs should Microsoft consider in determining the size of the carbon tax?


Denis Pepin/Shutterstock

What is the social cost of carbon?

In 2011, three leading economists, Nicholas Z. Muller, Robert Mendelsohn, and William Nordhaus, published a paper estimating the external cost of pollution by various U.S. industries. The costs took a variety of forms, from harmful effects on health to reduced agricultural yields. In the case of the electricity-generation sector, the authors included costs from carbon dioxide emissions—one of the many *greenhouse gases* that cause *climate change.*

The authors used a conservative, relatively low estimate because valuing these costs is a contentious issue—in part because they will fall on future generations. For each industry they calculated the total external cost of pollution, or TEC. Remarkably, in a number of cases this cost actually exceeded the industry's value added (VA), that is, the market value of its output. This doesn't mean that these industries should be shut down, but it's a clear indication that markets weren't taking the costs of pollution into account.

Among other things, the paper compared the external costs associated with coal-fired and natural gas–fired power plants. The accompanying table shows the TEC to VA ratios and the TEC to kilowatt-hour ratios for the coal and natural gas industries. As you can see, both modes of electricity generation impose large external costs, exceeding their value added. But the TEC per kilowatt-hour generated with natural gas is much lower than that of one generated with coal, because burning natural gas releases both less carbon dioxide and fewer other pollutants. A conservative estimate is that the external cost of a kilowatt hour is one-third of the retail price of electricity when generated by coal, and one-twentieth when generated by natural gas.

	TEC/VA	TEC/Kilowatt-hour
Coal	2.83	$0.039
Natural gas	1.30	0.005

In 2014, the Environmental Protection Agency (EPA) issued rules limiting carbon emissions from newly constructed power plants. The rules won't hinder the construction of gas-fired plants, which meet the EPA standard, but will block coal-fired plants unless they can use carbon-capture technology to divert carbon emissions and store them underground.

In addition, the falling price of natural gas due to fracking has induced power companies to substitute natural gas for coal in generating power. So in 2016, for the first time in history, more American energy was generated by using natural gas than by using coal.

>> *Check Your Understanding* 16-1

. Wastewater runoff from large poultry farms adversely affects their neighbors. Explain the following:

a. The nature of the external cost imposed

b. The outcome in the absence of government intervention or a private deal

c. The socially optimal outcome

. According to Yasmin, any student who borrows a book from the university library and fails to return it on time imposes a negative externality on other students. She claims that rather than charging a modest fine for late returns, the library should charge a huge fine so that borrowers will never return a book late. Is Yasmin's economic reasoning correct?

>> *Quick Review*

- External costs and benefits are known as **externalities.** Pollution is an example of an **external cost,** or **negative externality;** in contrast, some activities can give rise to **external benefits,** or **positive externalities.**
- There are costs as well as benefits to reducing pollution, so the optimal quantity of pollution isn't zero. Instead,

internalize the externality—to take into account the true cost to society of their actions.

The term *emissions tax* may convey the misleading impression that taxes are a solution to only one kind of external cost, pollution. In fact, taxes can be used to discourage any activity that generates negative externalities, such as driving (which inflicts environmental damage greater than the cost of producing gasoline) or smoking (which inflicts health costs on society far greater than the cost of making a cigarette).

In general, taxes designed to reduce external costs are known as **Pigouvian taxes**, after the economist A. C. Pigou, who emphasized their usefulness in his classic 1920 book, *The Economics of Welfare*. In our example, the optimal Pigouvian tax is $200. As you can see from Figure 16-2, this corresponds to the marginal social cost of pollution at the optimal output quantity, Q_{OPT}.

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

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

GLOBAL COMPARISON ECONOMIC GROWTH AND GREENHOUSE GASES IN SIX COUNTRIES

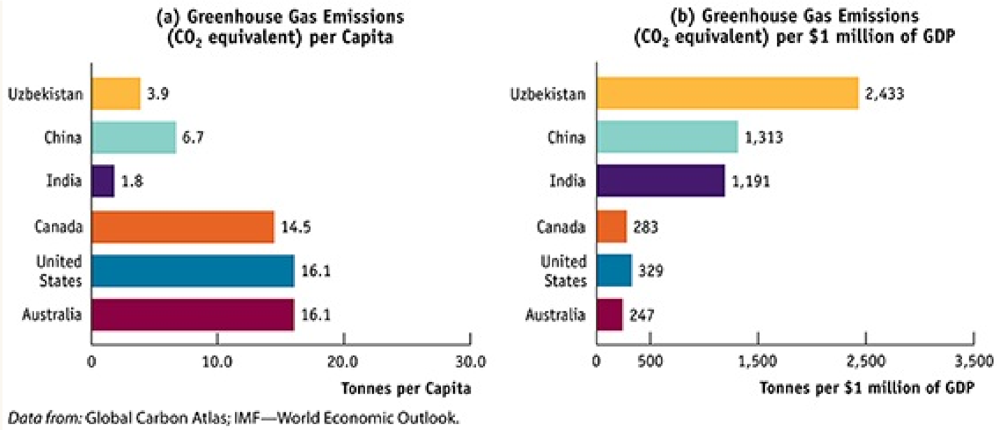
At first glance, a comparison of the per capita greenhouse gas emissions of various countries, shown in panel (a) of this graph, suggests that Australia, Canada, and the United States are the worst offenders. The average American is responsible for 16.1 tonnes of greenhouse gas emissions (measured in carbon dioxide, CO_2, equivalents)—the pollution that causes climate change—compared to only 3.9 tonnes for the average Uzbek, 6.7 tonnes for the average Chinese, and 1.8 tonnes for the average Indian. (A tonne, also called a metric ton, equals 1.10 ton.)

Such a conclusion, however, ignores an important factor in determining the level of a country's greenhouse gas emissions: its gross domestic product, or GDP—the total value of a country's domestic output. Output typically cannot be produced without more energy, and more energy usage typically results in more pollution. In fact, some have argued that criticizing a country's level of greenhouse gases without taking account of its level of economic development is misguided. It would be equivalent to faulting a country for being at a more advanced stage of economic development.

A more meaningful way to compare pollution across countries is to measure emissions per $1 million of a country's GDP, as shown in panel (b). On this basis, the United States, Canada, and Australia are now "green" countries, but China, India, and Uzbekistan are not. What explains the reversal once GDP is accounted for? The answer is scarce resources.

Countries that are poor, such as Uzbekistan and India (and, historically, China), have viewed resources spent on pollution reduction as better spent on other things. They have argued that they are too poor to afford the same environmental priorities as wealthy advanced countries. To impose a wealthy country's environmental standards on them would, they claimed, jeopardize their economic growth.

However, the scientific evidence pointing to *greenhouse gases* as the cause of *climate change* and the falling price of non-polluting energy sources has changed attitudes in poorer countries. Realizing that their citizens are likely to suffer disproportionately more from climate change, poor countries joined forces with rich countries to sign the *Paris Agreement* in 2015, an agreement between 196 countries to limit their greenhouse gas emissions in order to avoid the adverse effects of climate change.



Tradable Emissions Permits

Tradable emissions permits are licenses to emit limited quantities of pollutants that can be bought and sold by polluters. Tradable emissions permits work in practice much like the tradable quotas (discussed in Chapter 5) in which regulators created a system of tradable licenses to fish for crabs. The tradable licenses resulted in an efficient way to allocate the right to fish—boat-owners with the safest and lowest cost of operation purchase the rights of owners with less safe, higher cost boats. Although tradable emissions permits involve trading a "bad" like pollution instead of a "good" like crab, both systems work to allocate an activity efficiently because the permits, like licenses, are *tradable*.

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

Here's why this system works in the case of pollution. Firms that pollute typically have different costs of reducing pollution—for example, it will be more costly for plants using older technology to reduce pollution than plants using newer technology. Regulators begin the system by issuing polluters with permits to pollute based on some formula—say, for example, equal to 50% of a given firm's historical level of emissions. Firms then have the right to trade permits among themselves.

Provided that the market price of a permit is the same as the optimal emissions tax, the two systems arrive at the same outcome.

The Economics of Climate Change and the Great Energy Transition

One serious problem that the world will face in upcoming years is **climate change.** Science has conclusively shown that emissions of *greenhouse gases* are changing the earth's climate. On a global scale, **greenhouse gases** trap heat in Earth's atmosphere, leading to extreme weather patterns around the world—drought, flooding, extreme temperatures, destructive storm activity, and rising sea levels. Climate change inflicts huge costs and suffering, as crops fail, homes are washed away, tropical diseases spread, animal species are lost, and areas become uninhabitable. A recent estimate put the cost of unmitigated climate change at 20% of world gross domestic product by 2100.

> An accumulation of greenhouse gases caused by the use of fossil fuels has led to changes in the earth's climate, known as **climate change.**

> **Greenhouse gases** are gas emissions that trap heat in Earth's atmosphere.

The rise in Earth's temperature began in the first half of the nineteenth century and has accelerated since the 1980s. The source of the vast majority of greenhouse gases is human activity—specifically, the burning of **fossil fuels** such as coal, oil, and natural gas, which are derived from fossil sources and are used to generate electricity or power vehicles. While fossil fuels are in limited supply, **renewable energy sources** are inexhaustible. Examples are solar and wind-generated power. Unlike fossil fuels, renewables are **clean energy sources** because they do not emit greenhouse gases.

> **Fossil fuels** such as coal and oil are fuels derived from fossil sources.

> **Renewable energy sources** such as solar and wind power are inexhaustible sources of energy (unlike fossil fuel sources, which are exhaustible).

Clean energy sources are those that do not emit greenhouse gases. Renewable energy sources are also clean energy sources.

World energy consumption is overwhelmingly dependent upon fossil fuels, which account for 81.4% of total consumption, while renewables account for only 2.6%. Why? It's dollars and cents (or rupees, as the case may be). Historically, fossil fuels have been a cheaper source of energy than renewables.

However, it is now widely recognized that the direct cost of fossil fuel consumption greatly underestimates the social cost. Environmental economists have argued that the price per tonne of carbon should have been $103 in 2015, climbing to $260 by 2035, in order to account for its environmental costs. That's far more than the going carbon price in world markets. In the United States in 2015, that price stood at approximately $20 per tonne.

To address climate change, humans will need to move from a heavy reliance on fossil fuels to using clean energy sources, a process that we, the authors, refer to as the **great energy transition.** But because so much of the productive capacity of modern economies is dependent upon fossil fuel use, the transition will require economic changes and large-scale investment in clean energy capacity.

Great energy transition is the move from a heavy reliance on fossil fuels to using clean energy sources that are also renewable.

The adoption of government policies such as taxes, tax credits, subsidies, and mandates, as well as consumer use of smart metering and industrial commitments to clean energy use, are examples of some of the responses that will help bring about the great energy transition. Despite the magnitude of the task, progress has been made: between 2009 and 2016, the cost of solar power fell by 60% and wind power by 40%. In parts of Europe wind power is cost competitive, while in the sunny United States solar power is cost competitive.

ECONOMICS >> *in Action* Cap and Trade

The tradable emissions permit systems for both acid rain in the United States and greenhouse gases in the European Union are examples of *cap and trade systems:* the government sets a *cap* (a maximum amount of pollutant that can be emitted), issues tradable emissions permits, and enforces a yearly rule that a polluter must hold a number of permits equal to the amount of pollutant emitted. The goal is to set the cap low enough to generate environmental benefits, while giving polluters flexibility in meeting environmental standards and motivating them to adopt new technologies that will lower the cost of reducing pollution.

In 1994 the United States began a cap and trade system for the sulfur dioxide emissions that cause acid rain by issuing permits to power plants based on their historical consumption of coal. Thanks to the system, sulfur dioxide emissions have fallen by 75% from 1994 to 2015. Economists who have analyzed the sulfur dioxide cap and trade system point to another reason for its success: it would have been a lot more expensive—80% more to be exact—to reduce emissions by this much using a non-market-based regulatory policy.

In 2005 the first cap and trade system for trading greenhouse gases—called *carbon trading*—was launched in the European Union. In the decade since then, carbon trading has grown rapidly around the world and now covers 8% of all man-made greenhouse gas emissions. In the past five years, several new greenhouse gas markets have been launched covering California, South Korea, Quebec, and three major industrial centers in China. In 2015, approximately $75 billion in permits were traded globally.

Yet cap and trade systems are not silver bullets for the world's pollution problems. Although they are appropriate for pollution that's geographically dispersed, like sulfur dioxide and greenhouse gases, they don't work for pollution that's localized, like groundwater contamination. And there must be vigilant monitoring of compliance for the system to work. Finally, the level at which the cap is set has become a difficult political issue for governments trying to run an effective cap and trade system.

The political problems stem from the fact that a lower cap imposes higher costs on companies, because they must either achieve great pollution reductions or because they must purchase permits that command a higher market price. So companies lobby governments to set higher caps. As of 2015 only four countries (Finland, Sweden, Norway, and Switzerland) had caps that met or exceeded $44 per metric ton, the carbon price that the International Emissions Trading Association estimates is required to avert catastrophic climate change. In fact, most carbon trading prices are well below $15. As one energy economist stated, “It is politically difficult to get carbon prices to levels that have an effect.” And the same applies for taxes on carbon, as higher taxes can be a hard sell to consumers and producers.

So although carbon trading and carbon taxes are the efficient ways to reduce greenhouse emissions, their susceptibility to political pressure is making policy makers turn to regulations instead. A case in point is the adoption in 2014 by the EPA of rules limiting the emissions from newly built coal-fired and natural gas–fired plants. And in 2016, the Obama Administration adopted a mandate that doubles the fuel efficiency of cars by 2025.

>> *Check Your Understanding* 16-2

. Some opponents of tradable emissions permits object to them on the grounds that polluters that sell their permits benefit monetarily from their contribution to polluting the environment. Assess this argument.

. Explain the following.

a. Why an emissions tax smaller than or greater than the marginal social cost at Q_{OPT} leads to a smaller total surplus compared to the total surplus generated if the emissions tax had been set optimally

b. Why a system of tradable emissions permits that sets the total quantity of allowable pollution higher or lower than Q_{OPT} leads to a smaller total surplus compared to the total surplus generated if the number of permits had been set optimally

c. How a carbon tax, which is a tax on carbon emissions, would encourage consumers to use more renewable energy sources

>> *Quick Review*

SUMMARY

When pollution can be directly observed and controlled, government policies should be geared directly to producing the **socially optimal quantity of pollution,** the quantity at which the **marginal social cost of pollution** is equal to the **marginal social benefit of pollution.** In the absence of government intervention, a market produces too much pollution because polluters take only their benefit from polluting into account, not the costs imposed on others.

The costs to society of pollution are an example of an **external cost;** in some cases, however, economic activities yield **external benefits.** External costs and benefits are jointly known as **externalities,** with external costs called **negative externalities** and external benefits called **positive externalities.**

According to the **Coase theorem,** individuals can find a way to **internalize the externality,** making government intervention unnecessary, as long as **transaction costs**—the costs of making a deal—are sufficiently low. However, in many cases transaction costs are too high to permit such deals.

Governments often deal with pollution by imposing **environmental standards,** a method, economists argue, that is usually an inefficient way to reduce pollution. Two efficient (cost-minimizing) methods for reducing pollution are **emissions taxes,** a form of **Pigouvian tax,** and **tradable emissions permits.** The optimal Pigouvian tax on pollution is equal to its marginal social cost at the socially optimal quantity of pollution. These methods also provide incentives for the creation and adoption of production technologies that cause less pollution.

A history of heavy reliance on **fossil fuels** which emit **greenhouse gases** has led to problems created by **climate change.** Unlike fossil fuels, **renewable energy sources** are inexhaustible. Policies such as taxes, tax credits, subsidies, and mandates, as well as consumer use of smart metering and industrial commitments, can help ensure the **great energy transition**, a wide-scale shift towards renewable **clean energy sources.**

When a good or activity yields external benefits, or positive externalities, such as of exactly how the future will unfold. (The exception is our coverage of health insurance decisions.) Yet, as anyone who lives on the Atlantic Seaboard, or in the tornadoprone Great Plains, or in the drought-stricken Western states, now realizes, making decisions when the future is uncertain carries with it the *risk of loss*. In fact, both climatologists and the property insurance industry largely agree that extreme weather events have become more frequent as a result of climate change.

It is often possible for individuals to use markets to reduce their risk. For example, hurricane victims who had insurance were able to receive some, if not complete, compensation for their losses. In fact, through insurance and other devices, the modern economy offers many ways for individuals to reduce their exposure to risk.

However, a market economy cannot always solve the problems created by uncertainty. Markets do very well at coping with risk when two conditions hold: (1) when risk can be reasonably well *diversified* and (2) when the probability of loss is equally well known by everyone. Although, over the past several years, the increase in extreme weather events has led many insurers to stop relying on *diversification* for weather-related losses and sharply reduce their coverage of such losses.

But in practice, the second condition is often the more limiting one. Markets run into trouble when some people know things that others do not—a situation that involves what is called *private information*. We'll see that private information can cause inefficiency by preventing mutually beneficial transactions from occurring—especially in insurance markets.

In this chapter we'll examine why most people dislike risk. Then we'll explore how a market economy allows people to reduce risk at a price. Finally, we'll turn to the special problems created for markets by private information.

That is, polluters will face a marginal cost of polluting (the price of a permit) that is "too low"—lower than the marginal social cost at the socially optimal quantity of pollution. As a result, pollution will be greater than the socially optimal quantity. This is inefficient and lowers total surplus.

If the total level of allowable pollution is set too low, the supply of emissions permits will be low and so the equilibrium price at which permits trade will be high. That is, polluters will face a marginal cost of polluting (the price of a permit) that is "too high"—higher than the marginal social cost at the socially optimal quantity of pollution. As a result, pollution will be lower than the socially optimal quantity. This also is inefficient and lowers total surplus.

c. A carbon tax will increase the cost of using fossil fuels, including the prices of gasoline and coal. As the cost of fossil fuels increases, consumers will reduce their use of fossil fuels as energy sources. They will be increasingly likely to purchase more fuel-efficient cars and invest in solar technology for their homes.

16-3 Check Your Understanding

1. College education provides external benefits through the creation of knowledge. And student aid acts like a Pigouvian subsidy on higher education. If the marginal social benefit of higher education is indeed $29 billion, then student aid is an optimal policy.

2.

a. Planting trees generates an external benefit since many people (not just those who plant the trees) benefit from the increased air quality and lower summer temperatures. Without a subsidy, people will plant too few trees, setting the marginal social cost of planting a tree—what they forgo by planting a tree—too low. (Although too low, it may still be more than zero since a homeowner gains some personal benefit from planting a tree.) A Pigouvian subsidy will induce people to plant more trees, bringing the marginal social benefit of planting a tree in line with the marginal social cost.

b. Water-saving toilets generate an external benefit because they discourage wasting