chapter: 2

Economic Models: Trade-offs and Trade

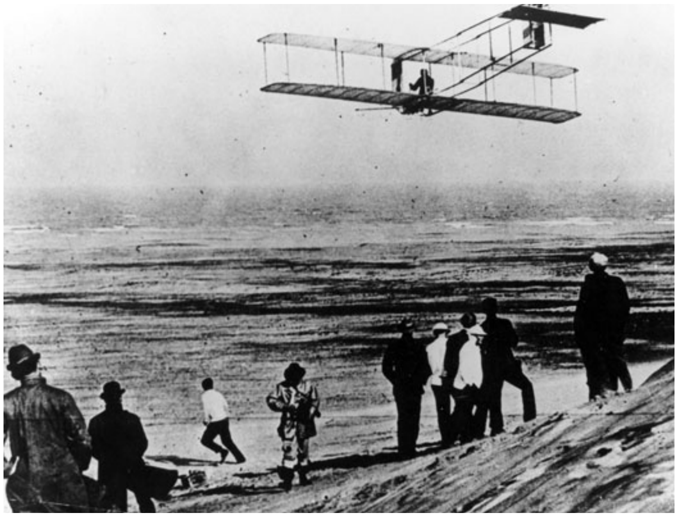
TUNNEL VISION

IN 1901 WILBUR AND ORVILLE WRIGHT BUILT something that would change the world. No, not the airplane—their successful flight at Kitty Hawk would come two years later. What made the Wright brothers true visionaries was their wind tunnel, an apparatus that let them experiment with many different designs for wings and control surfaces. These experiments gave them the knowledge that would make heavier-than-air flight possible.

A miniature airplane sitting motionless in a wind tunnel isn't the same thing as an actual aircraft in flight. But it is a very useful model of a flying plane—a simplified representation of the real thing that can be used to answer crucial questions, such as how much lift a given wing shape will generate at a given airspeed.

Needless to say, testing an airplane design in a wind tunnel is cheaper and safer than building a full-scale version and hoping it will fly. More generally, models play a crucial role in almost all scientific research—economics very much included.

In fact, you could say that economic theory consists mainly of a collection of models, a series of simplified representations of economic reality that allow us to understand a variety of economic issues. In this chapter, we will look at two economic models that are crucially important in their own right and also illustrate why such models are so useful. We'll conclude with a look at how economists actually use models in their work.



Landov Photos

Clearly, the Wright brothers believed in their model.

WHAT YOU WILL LEARN IN THIS CHAPTER:

- Why **models**—simplified representations of reality—play a crucial role in economics
- Two simple but important models: the **production possibility frontier** and **comparative advantage**
- The **circular-flow diagram,** a schematic representation of the economy
- The difference between **positive economics,** which tries to describe the economy and predict its behavior, and **normative economics,** which tries to prescribe economic policy
- When economists agree and why they sometimes disagree

A **model** is a simplified representation of a real situation that is used to better understand real-life situations.

The **other things equal assumption** means that all other relevant factors remain unchanged.

Models in Economics: Some Important Examples

A **model** is any simplified representation of reality that is used to better understand real-life situations. But how do we create a simplified representation of an economic situation?

One possibility—an economist's equivalent of a wind tunnel—is to find or create a real but simplified economy. For example, economists interested in the economic role of money have studied the system of exchange that developed in World War II prison camps, in which cigarettes became a universally accepted form of payment even among prisoners who didn't smoke.

Another possibility is to simulate the workings of the economy on a computer. For example, when changes in tax law are proposed, government officials use *tax models*—large mathematical computer programs—to assess how the proposed changes would affect different types of people.

Models are important because their simplicity allows economists to focus on the effects of only one change at a time. That is, they allow us to hold everything else constant and study how one change affects the overall economic outcome. So an important assumption when building economic models is the **other things equal assumption,** which means that all other relevant factors remain unchanged.

But you can't always find or create a small-scale version of the whole economy, and a computer program is only as good as the data it uses. (Programmers have a saying: garbage in, garbage out.) For many purposes, the most effective form of economic modeling is the construction of "thought experiments": simplified, hypothetical versions of real-life situations.

In Chapter 1 we illustrated the concept of equilibrium with the example of how customers at a supermarket would rearrange themselves when a new cash register opens. Though we didn't say it, this was an example of a simple model—an imaginary

FOR INQUIRING MINDS

Models for Money

What's an economic model worth, anyway? In some cases, quite a lot of money.

Although many economic models are developed for purely scientific purposes, others are developed to help governments make economic policies. And there is a growing business in developing economic models to help corporations make decisions.

Who models for money? There are dozens of consulting firms that use models to predict future trends, offer advice based on their models, or develop custom models for business and government clients. A notable example is Global Insight, the world's biggest economic consulting firm. It was created by a merger between Data Resources, Inc., founded by professors from Harvard and MIT, and Wharton Economic Forecasting Associates, founded by professors at the University of Pennsylvania.

One particularly lucrative branch of economics is finance theory, which helps investors figure out what assets, such as shares in a company, are worth. Finance theorists often become highly paid "rocket scientists" at big Wall Street firms because financial models demand a high level of technical expertise.

Unfortunately, the most famous business application of finance theory came spectacularly to grief. In 1994 a group of Wall Street traders teamed up with famous finance theorists—including two Nobel Prize winners—to form Long-Term Capital Management (LTCM), a fund that used sophisticated financial models to invest the money of wealthy clients. At first, the fund did very well. But in 1998 bad economic news from all over the world—with countries as disparate as Russia, Japan, and Brazil in financial trouble at the same time—inflicted huge losses on LTCM's investments. For a few anxious days, many people feared not only that the fund would collapse but also that it would bring many other companies down with it. Thanks in part to a rescue operation organized by government officials, this did not happen; but LTCM was closed a few months later, having lost millions of dollars and with some of its investors losing most of the money they had put in.

What went wrong? Partly it was bad luck. But experienced hands also faulted the economists at LTCM for taking too many risks. Although LTCM's models indicated that a run of bad news like the one that actually happened was extremely unlikely, a sensible economist knows that sometimes even the best model misses important possibilities.

Interestingly, a similar phenomenon occurred in the summer of 2007, when problems in the financial market for home mortgage loans caused severe losses for several investment funds. It turns out that these funds had made the same mistake as LTCM—omitting from their models the possibility of a severe downturn in the home mortgage loan market.

supermarket, in which many details were ignored (what are the customers buying? never mind), that could be used to answer a "what if" question: what if another cash register were opened?

The **production possibility frontier** illustrates the trade-offs facing an economy that produces only two goods. It shows the maximum quantity of one good that can be produced for any given quantity produced of the other.

As the cash register story showed, it is often possible to describe and analyze a useful economic model in plain English. However, because much of economics involves changes in quantities—in the price of a product, the number of units produced, or the number of workers employed in its production—economists often find that using some mathematics helps clarify an issue. In particular, a numerical example, a simple equation, or—especially—a graph can be key to understanding an economic concept.

Whatever form it takes, a good economic model can be a tremendous aid to understanding. The best way to grasp this point is to consider some simple but important economic models and what they tell us. First, we will look at the *production possibility frontier,* a model that helps economists think about the trade-offs every economy faces. Then we will turn to *comparative advantage,* a model that clarifies the principle of gains from trade—trade both between individuals and between countries. In addition, we'll examine the *circular-flow diagram,* a schematic representation that helps us understand how flows of money, goods, and services are channeled through the economy.

In discussing these models, we make considerable use of graphs to represent mathematical relationships. Such graphs will play an important role throughout this book. If you are already familiar with the use of graphs, the material that follows should not present any problem. If you are not, this would be a good time to turn to the appendix of this chapter, which provides a brief introduction to the use of graphs in economics.

Trade-offs: The Production Possibility Frontier

The hit movie *Cast Away,* starring Tom Hanks, was an update of the classic story of Robinson Crusoe, the hero of Daniel Defoe's eighteenth-century novel. Hanks played the sole survivor of a plane crash, stranded on a remote island. As in the original story of Robinson Crusoe, the character played by Hanks had limited resources: the natural resources of the island, a few items he managed to salvage from the plane, and, of course, his own time and effort. With only these resources, he had to make a life. In effect, he became a one-man economy.

The first principle of economics we introduced in Chapter 1 was that resources are scarce and that, as a result, any economy—whether it contains one person or millions of people—faces trade-offs. For example, if a castaway devotes resources to catching fish, he cannot use those same resources to gather coconuts.

To think about the trade-offs that face any economy, economists often use the model known as the **production possibility frontier.** The idea behind this model is to improve our understanding of trade-offs by considering a simplified economy that produces only two goods. This simplification enables us to show the trade-off graphically.

What to do? Even a castaway faces trade-offs.

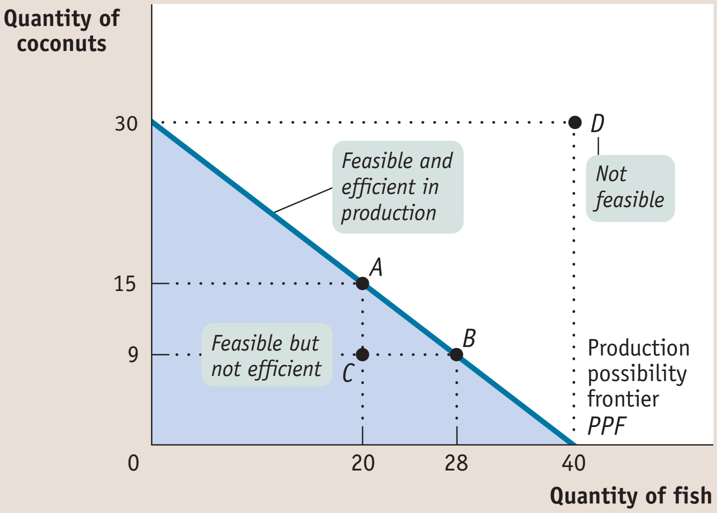
Figure 2-1 on the next page shows a hypothetical production possibility frontier for Tom, a castaway alone on an island, who must make a trade-off between production of fish and production of coconuts. The frontier—the line in the diagram—shows the maximum quantity of fish Tom can catch during a week *given* the quantity of coconuts he gathers, and vice versa. That is, it answers questions of the form, "What is the maximum quantity of fish Tom can catch if he also gathers 9 (or 15, or 30) coconuts?"

There is a crucial distinction between points *inside* or *on* the production possibility frontier (the shaded area) and *outside* the frontier. If a production point lies inside or on the frontier—like point *C,* at which Tom catches 20 fish and gathers 9 coconuts—it is feasible. After all, the frontier tells us that if Tom catches 20 fish, he could also gather a maximum of 15 coconuts, so he could

FIGURE 2-1

The Production Possibility Frontier

The production possibility frontier illustrates the trade-offs facing an economy that produces two goods. It shows the maximum quantity of one good that can be produced given the quantity of the other good produced. Here, the maximum quantity of coconuts that Tom can gather depends on the quantity of fish he catches, and vice versa. His feasible production is shown by the area *inside* or *on* the curve. Production at point *C* is feasible but not efficient. Points *A* and *B* are feasible and efficient in production, but point *D* is not feasible.



certainly gather 9 coconuts. However, a production point that lies outside the frontier—such as the hypothetical production point *D,* where Tom catches 40 fish and gathers 30 coconuts—isn't feasible. (In this case, Tom could catch 40 fish and gather no coconuts *or* he could gather 30 coconuts and catch no fish, but he can't do both.)

In Figure 2-1 the production possibility frontier intersects the horizontal axis at 40 fish. This means that if Tom devoted all his resources to catching fish, he would catch 40 fish per week but would have no resources left over to gather coconuts. The production possibility frontier intersects the vertical axis at 30 coconuts. This means that if Tom devoted all his resources to gathering coconuts, he could gather 30 coconuts per week but would have no resources left over to catch fish.

The figure also shows less extreme trade-offs. For example, if Tom decides to catch 20 fish, he is able to gather at most 15 coconuts; this production choice is illustrated by point *A*. If Tom decides to catch 28 fish, he can gather at most only 9 coconuts, as shown by point *B*.

Thinking in terms of a production possibility frontier simplifies the complexities of reality. The real-world economy produces millions of different goods. Even a castaway on an island would produce more than two different items (for example, he would need clothing and housing as well as food). But in this model we imagine an economy that produces only two goods.

By simplifying reality, however, the production possibility frontier helps us understand some aspects of the real economy better than we could without the model: efficiency, opportunity cost, and economic growth.

Efficiency First of all, the production possibility frontier is a good way to illustrate the general economic concept of *efficiency*. Recall from Chapter 1 that an economy is efficient if there are no missed opportunities—there is no way to make some people better off without making other people worse off.

One key element of efficiency is that there are no missed opportunities in production—there is no way to produce more of one good without producing less of other goods. As long as Tom is on the production possibility frontier, his production is efficient. At point *A,* the 15 coconuts he gathers are the maximum quantity he can get *given* that he has chosen to catch 20 fish; at point *B,* the 9 coconuts he gathers are the maximum he can get *given* his choice to catch 28 fish; and so on. If an economy is producing at a point on its production possibility frontier, we say that the economy is *efficient in production*.

But suppose that for some reason Tom was at point *C,* producing 20 fish and 9 coconuts. Then this one-person economy would definitely not be efficient in production, and would therefore be *inefficient:* it could be producing more of both goods. Another example of this occurs when people are involuntarily unemployed: they want to work but are unable to find jobs. When that happens, the economy is not efficient in production because it could be producing more output if these people were employed.

Although the production possibility frontier helps clarify what it means for an economy to be efficient in production, it's important to understand that efficiency in production is only *part* of what's required for the economy as a whole to be efficient. Efficiency also requires that the economy allocate its resources so that consumers are as well off as possible. If an economy does this, we say that it is *efficient in allocation*. To see why efficiency in allocation is as important as efficiency in production, notice that points A and B in Figure 2-1 both represent situations in which the economy is efficient in production, because in each case it can't produce more of one good without producing less of the other. But these two situations may not be equally desirable. Suppose that Tom prefers point *B* to point *A*—that is, he would rather consume 28 fish and 9 coconuts than 20 fish and 15 coconuts. Then point *A* is inefficient from the point of view of the economy as a whole: it's possible to make Tom better off without making anyone else worse off. (Of course, in this castaway economy there isn't anyone else: Tom is all alone.)

This example shows that efficiency for the economy as a whole requires *both* efficiency in production and efficiency in allocation: to be efficient, an economy must produce as much of each good as it can given the production of other goods, and it must also produce the mix of goods that people want to consume. In the real world, command economies, such as the former Soviet Union, were notorious for inefficiency in allocation. For example, it was common for consumers to find a store stocked with a few odd items of merchandise, but lacking such basics as soap and toilet paper.

Opportunity Cost The production possibility frontier is also useful as a reminder of the fundamental point that the true cost of any good is not just the amount of money it costs to buy, but everything else in addition to money that must be given up in order to get that good—the *opportunity cost*. If, for example, Tom decides to go from point *A* to point *B,* he will produce 8 more fish but 6 fewer coconuts. So the opportunity cost of those 8 fish is the 6 coconuts not gathered. Since 8 extra fish have an opportunity cost of 6 coconuts, each 1 fish has an opportunity cost of $6/8 = 3/4$ of a coconut.

Is the opportunity cost of an extra fish in terms of coconuts always the same, no matter how many fish Tom catches? In the example illustrated by Figure 2-1, the answer is yes. If Tom increases his catch from 28 to 40 fish, the number of coconuts he gathers falls from 9 to zero. So his opportunity cost per additional fish is $9/12 = 3/4$ of a coconut, the same as it was when he went from 20 fish caught to 28. However, the fact that in this example the opportunity cost of an additional fish in terms of coconuts is always the same is a result of an assumption we've made, an assumption that's reflected in how Figure 2-1 is drawn. Specifically, whenever we assume that the opportunity cost of an additional unit of a good doesn't change regardless of the output mix, the production possibility frontier is a straight line.

Moreover, as you might have already guessed, the slope of a straight-line production possibility frontier is equal to the opportunity cost—specifically, the opportunity cost for the good measured on the horizontal axis in terms of the good measured on the vertical axis. In Figure 2-1, the production possibility frontier has a *constant slope* of $-3/4$, implying that Tom faces a *constant opportunity cost* for 1 fish equal to $3/4$ of a coconut. (A review of how to calculate the slope of a straight line is found in this chapter's appendix.) This is the simplest case, but the production possibility frontier model can also be used to examine situations in which opportunity costs change as the mix of output changes.

FIGURE 2-2

Increasing Opportunity Cost

The bowed-out shape of the production possibility frontier reflects increasing opportunity cost. In this example, to produce the first 20 fish, Tom must give up 5 coconuts. But to produce an additional 20 fish, he must give up 25 more coconuts.

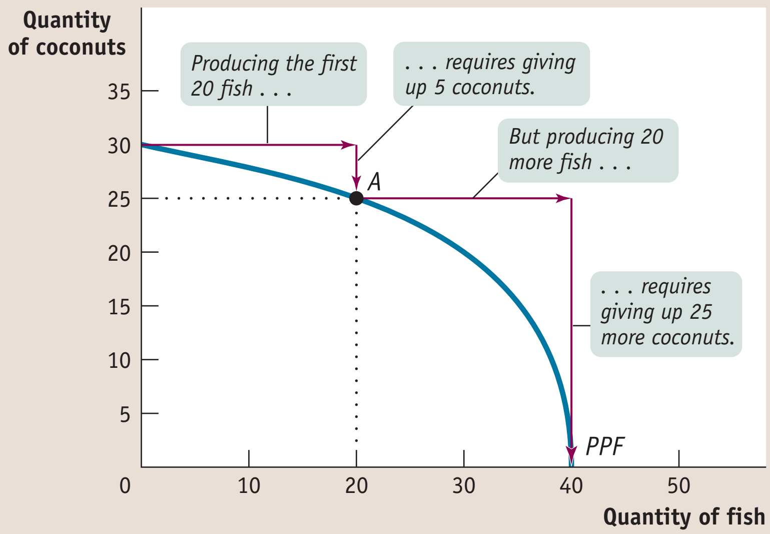


Figure 2-2 illustrates a different assumption, a case in which Tom faces *increasing opportunity cost*. Here, the more fish he catches, the more coconuts he has to give up to catch an additional fish, and vice versa. For example, to go from producing zero fish to producing 20 fish, he has to give up 5 coconuts. That is, the opportunity cost of those 20 fish is 5 coconuts. But to increase his fish production to 40—that is, to produce an additional 20 fish—he must give up 25 more coconuts, a much higher opportunity cost. As you can see in Figure 2-2, when opportunity costs are increasing rather than constant, the production possibility frontier is a bowed-out curve rather than a straight line.

Although it's often useful to work with the simple assumption that the production possibility frontier is a straight line, economists believe that in reality opportunity costs are typically increasing. When only a small amount of a good is produced, the opportunity cost of producing that good is relatively low because the economy needs to use only those resources that are especially well suited for its production. For example, if an economy grows only a small amount of corn, that corn can be grown in places where the soil and climate are perfect for corn-growing but less suitable for growing anything else, like wheat. So growing that corn involves giving up only a small amount of potential wheat output. Once the economy grows a lot of corn, however, land that is well suited for wheat but isn't so great for corn must be used to produce corn anyway. As a result, the additional corn production involves sacrificing considerably more wheat production. In other words, as more of a good is produced, its opportunity cost typically rises because well-suited inputs are used up and less adaptable inputs must be used instead.

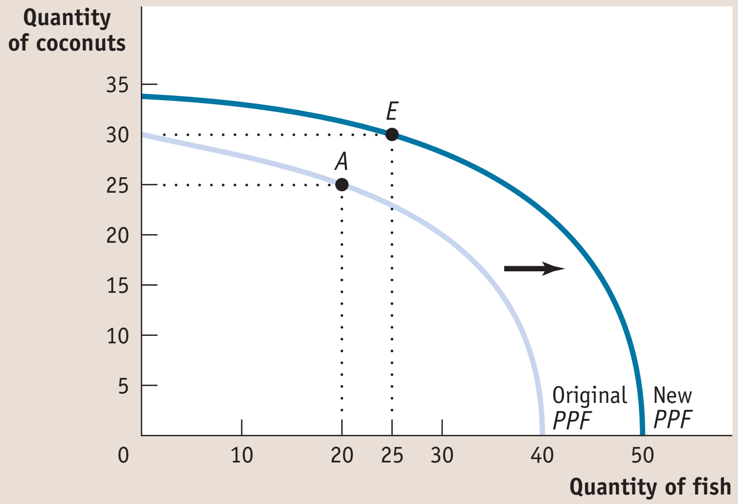
Economic Growth Finally, the production possibility frontier helps us understand what it means to talk about *economic growth*. We introduced the concept of economic growth in the Introduction, defining it as *the growing ability of the economy to produce goods and services*. As we saw, economic growth is one of the fundamental features of the real economy. But are we really justified in saying that the economy has grown over time? After all, although the U.S. economy produces more of many things than it did a century ago, it produces less of other things—for example, horse-drawn carriages. Production of many goods, in other words, is actually down. So how can we say for sure that the economy as a whole has grown?

The answer, illustrated in Figure 2-3, is that economic growth means an *expansion of the economy's production possibilities:* the economy *can* produce more of everything. For example, if Tom's production is initially at point *A* (20 fish and 25 coconuts),

FIGURE 2-3

Economic Growth

Economic growth results in an *outward shift* of the production possibility frontier because production possibilities are expanded. The economy can now produce more of everything. For example, if production is initially at point *A* (20 fish and 25 coconuts), it could move to point *E* (25 fish and 30 coconuts).



economic growth means that he could move to point *E* (25 fish and 30 coconuts). *E* lies outside the original frontier; so in the production possibility frontier model, growth is shown as an outward shift of the frontier.

What can lead the production possibility frontier to shift outward? There are basically two sources of economic growth. One is an increase in the economy's **factors of production,** the resources used to produce goods and services. Economists usually use the term *factor of production* to refer to a resource that is not used up in production. For example, workers use sewing machines to convert cloth into shirts; the workers and the sewing machines are factors of production, but the cloth is not. Once a shirt is made, a worker and a sewing machine can be used to make another shirt; but the cloth used to make one shirt cannot be used to make another. Broadly speaking, the main factors of production are the resources land, labor, capital, and human capital. Land is a resource supplied by nature; labor is the economy's pool of workers; capital refers to "created" resources such as machines and buildings; and human capital refers to the educational achievements and skills of the labor force, which enhance its productivity. Of course, each of these is really a category rather than a single factor: land in North Dakota is quite different from land in Florida.

To see how adding to an economy's factors of production leads to economic growth, suppose that Tom finds a fishing net washed ashore on the beach that is larger than the net he currently uses. The fishing net is a factor of production, a resource he can use to produce more fish in the course of a day spent fishing. We can't say how many more fish Tom will catch; that depends on how much time he decides to spend fishing now that he has the larger net. But because the larger net makes his fishing more productive, he can catch more fish without reducing the number of coconuts he gathers, or gather more coconuts without reducing his fish catch. So his production possibility frontier shifts outward.

The other source of economic growth is progress in **technology,** the technical means for the production of goods and services. Suppose Tom figures out a better way either to catch fish or to gather coconuts—say, by inventing a fishing hook or a wagon for transporting coconuts. Either invention would shift his production possibility frontier outward. In real-world economies, innovations in the techniques we use to produce goods and services have been a crucial force behind economic growth.

Again, economic growth means an increase in what the economy *can* produce. What the economy actually produces depends on the choices people make. After his production possibilities expand, Tom might not choose to produce both more fish and more

Factors of production are resources used to produce goods and services.

Technology is the technical means for producing goods and services.

coconuts—he might choose to increase production of only one good, or he might even choose to produce less of one good. For example, if he gets better at catching fish, he might decide to go on an all-fish diet and skip the coconuts—just as the introduction of motor vehicles led most people to give up on horse-drawn carriages. But even if, for some reason, he chooses to produce either fewer coconuts or fewer fish than before, we would still say that his economy has grown—because he *could* have produced more of everything.

The production possibility frontier is a very simplified model of an economy. Yet it teaches us important lessons about real-life economies. It gives us our first clear sense of what constitutes economic efficiency, it illustrates the concept of opportunity cost, and it makes clear what economic growth is all about.

Comparative Advantage and Gains from Trade

Among the twelve principles of economics described in Chapter 1 was the principle of *gains from trade*—the mutual gains that individuals can achieve by specializing in doing different things and trading with one another. Our second illustration of an economic model is a particularly useful model of gains from trade—trade based on *comparative advantage*.

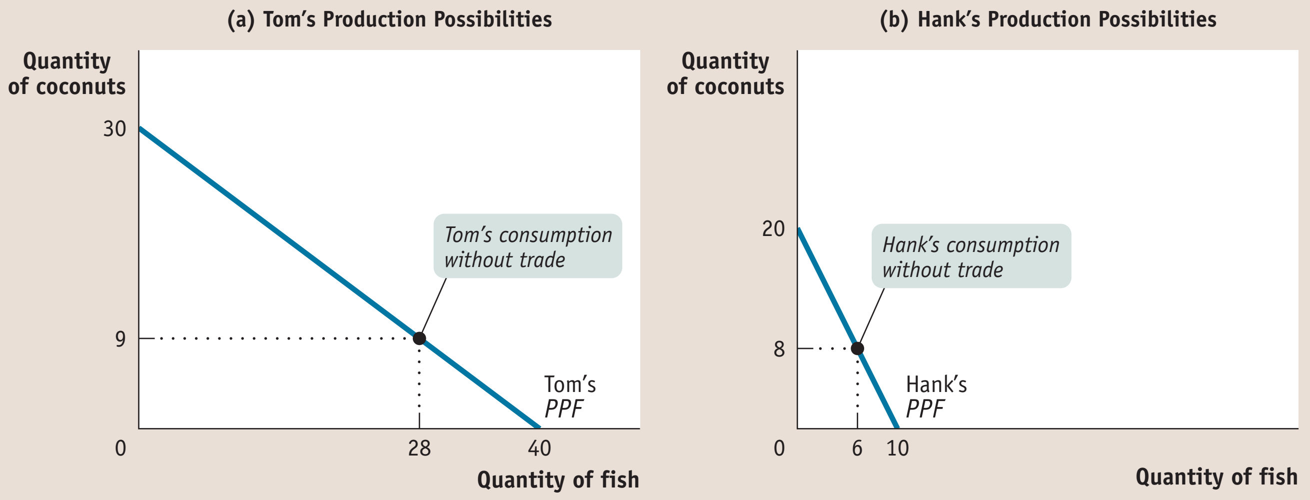
Let's stick with Tom stranded on his island, but now let's suppose that a second castaway, who just happens to be named Hank, is washed ashore. Can they benefit from trading with each other?

It's obvious that there will be potential gains from trade if the two castaways do different things particularly well. For example, if Tom is a skilled fisherman and Hank is very good at climbing trees, clearly it makes sense for Tom to catch fish and Hank to gather coconuts—and for the two men to trade the products of their efforts.

But one of the most important insights in all of economics is that there are gains from trade even if one of the trading parties isn't especially good at anything. Suppose, for example, that Hank is less well suited to primitive life than Tom; he's not nearly as good at catching fish, and compared to Tom even his coconut-gathering leaves something to be desired. Nonetheless, what we'll see is that both Tom and Hank can live better by trading with each other than either could alone.

For the purposes of this example, let's go back to the simpler case of straight-line production possibility frontiers. Tom's production possibilities are represented by the

FIGURE 2-4 **Production Possibilities for Two Castaways**



Here, each of the two castaways has a constant opportunity cost of fish and a straight-line production possibility frontier. In Tom's case, each fish always has an opportunity cost of ¾ of a coconut. In Hank's case, each fish always has an opportunity cost of 2 coconuts.

production possibility frontier in panel (a) of Figure 2-4, which is the same as the production possibility frontier in Figure 2-1. According to this diagram, Tom could catch 40 fish, but only if he gathered no coconuts, and could gather 30 coconuts, but only if he caught no fish, as before. Recall that this means that the slope of his production possibility frontier is –3/4: his opportunity cost of 1 fish is 3/4 of a coconut.

An individual has a **comparative advantage** in producing a good or service if the opportunity cost of producing the good or service is lower for that individual than for other people.

Panel (b) of Figure 2-4 shows Hank's production possibilities. Like Tom's, Hank's production possibility frontier is a straight line, implying a constant opportunity cost of fish in terms of coconuts. His production possibility frontier has a constant slope of –2. Hank is less productive all around: at most he can produce 10 fish or 20 coconuts. But he is particularly bad at fishing; whereas Tom sacrifices 3/4 of a coconut per fish caught, for Hank the opportunity cost of a fish is 2 whole coconuts. Table 2-1 summarizes the two castaways' opportunity costs of fish and coconuts.

TABLE 2-1

Tom's and Hank's Opportunity Costs of Fish and Coconuts

	Tom's Opportunity Cost	Hank's Opportunity Cost
One fish	3/4 coconut	2 coconuts
One coconut	4/3 fish	1/2 fish

Now, Tom and Hank could go their separate ways, each living on his own side of the island, catching his own fish and gathering his own coconuts. Let's suppose that they start out that way and make the consumption choices shown in Figure 2-4: in the absence of trade, Tom consumes 28 fish and 9 coconuts per week, while Hank consumes 6 fish and 8 coconuts.

But is this the best they can do? No, it isn't. Given that the two castaways have different opportunity costs, they can strike a deal that makes both of them better off.

Table 2-2 shows how such a deal works: Tom specializes in the production of fish, catching 40 per week, and gives 10 to Hank. Meanwhile, Hank specializes in the production of coconuts, gathering 20 per week, and gives 10 to Tom. The result is shown in Figure 2-5 on the next page. Tom now consumes more of both goods than before: instead of 28 fish and 9 coconuts, he consumes 30 fish and 10 coconuts. And Hank also consumes more, going from 6 fish and 8 coconuts to 10 fish and 10 coconuts. As Table 2-2 also shows, both Tom and Hank experience gains from trade: Tom's consumption of fish increases by two, and his consumption of coconuts increases by one. Hank's consumption of fish increases by four, and his consumption of coconuts increases by two.

So both castaways are better off when they each specialize in what they are good at and trade. It's a good idea for Tom to catch the fish for both of them because his opportunity cost of a fish is only 3/4 of a coconut not gathered versus 2 coconuts for Hank. Correspondingly, it's a good idea for Hank to gather coconuts for both of them.

Or we could put it the other way around: Because Tom is so good at catching fish, his opportunity cost of gathering coconuts is high: 4/3 of a fish not caught for every coconut gathered. Because Hank is a pretty poor fisherman, his opportunity cost of gathering coconuts is much less, only 1/2 of a fish per coconut.

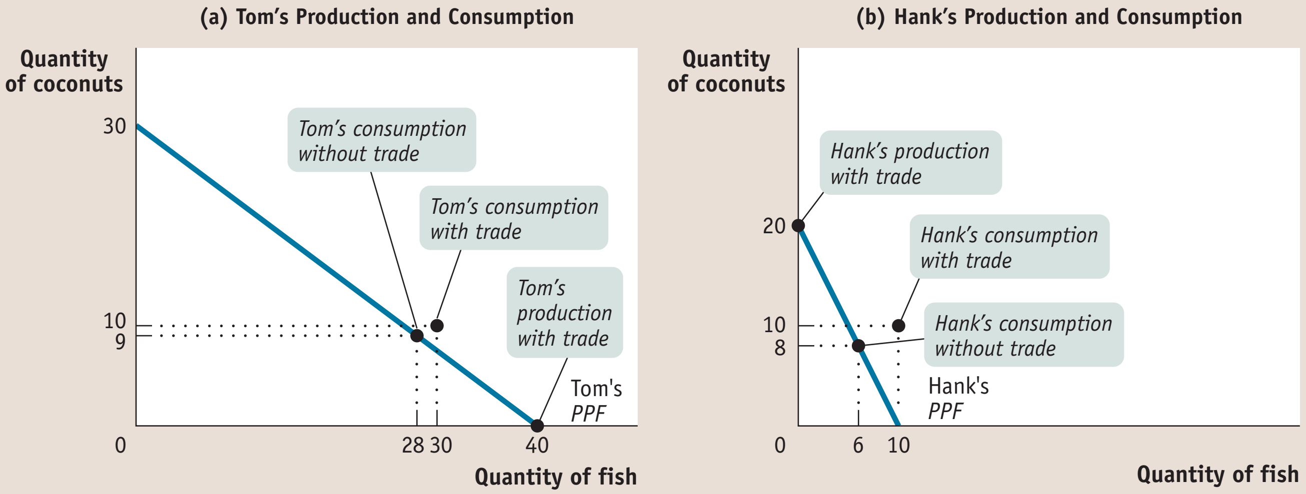
What we would say in this case is that Tom has a comparative advantage in catching fish and Hank has a comparative advantage in gathering coconuts. An individual has a **comparative advantage** in producing something if the opportunity cost of that production is lower for that individual than for other people. In other words, Hank has a comparative advantage over Tom in producing a particular good or service if Hank's opportunity cost of producing that good or service is lower than Tom's.

TABLE 2-2

How the Castaways Gain from Trade

		Without Trade		With Trade		Gains from Trade
		Production	Consumption	Production	Consumption	
Tom	Fish	28	28	40	30	+2
	Coconuts	9	9	0	10	+1
Hank	Fish	6	6	0	10	+4
	Coconuts	8	8	20	10	+2

FIGURE 2-5 **Comparative Advantage and Gains From Trade**



By specializing and trading, the two castaways can produce and consume more of both goods. Tom specializes in catching fish, his comparative advantage, and Hank—who has an *absolute* disadvantage in both goods but a *comparative* advantage in coconuts—specializes in gathering coconuts. The result is that each castaway can consume more of both goods than either could without trade.

One point of clarification before we proceed further. You may have wondered why Tom and Hank traded 10 fish for 10 coconuts. Why not some other deal, like trading 15 coconuts for 5 fish? The answer to that question has two parts. First, there may indeed be deals other than 10 fish for 10 coconuts that Tom and Hank are willing to agree to. Second, there are some deals that we can, however, safely rule out—one like 15 coconuts for 5 fish. To understand why, reexamine Table 2-1 and consider Hank first. When Hank works on his own without trading with Tom, his opportunity cost of 1 fish is 2 coconuts. Therefore, it's clear that Hank will not accept any deal with Tom in which he must give up more than 2 coconuts per fish—otherwise, he's better off not trading at all. So we can rule out a deal that requires Hank to pay 3 coconuts per fish—such as trading 15 coconuts for 5 fish. But Hank will accept a trade in which he pays less than 2 coconuts per fish—such as paying 1 coconut for 1 fish. Likewise, Tom will reject a deal that requires him to give up more than 4/3 of a fish per coconut. For example, Tom would refuse a trade that required him to give up 10 fish for 6 coconuts. But he will accept a deal where he pays less than 4/3 of a fish per coconut—and 1 fish for 1 coconut works. You can check for yourself why a trade of 1 fish for 1.5 coconuts would also be acceptable to both Tom and Hank. So the point to remember is that Tom and Hank will be willing to engage in a trade only if the "price" of the good each person is obtaining from the trade is less than his own opportunity cost of producing the good himself. Moreover, that's a general statement that is true whenever two parties trade voluntarily.

The story of Tom and Hank clearly simplifies reality. Yet it teaches us some very important lessons that apply to the real economy, too.

First, the model provides a clear illustration of the gains from trade: by agreeing to specialize and provide goods to each other, Tom and Hank can produce more and therefore both be better off than if they tried to be self-sufficient.

Second, the model demonstrates a very important point that is often overlooked in real-world arguments: as long as people have different opportunity costs, *everyone has a comparative advantage in something, and everyone has a comparative disadvantage in something*.

Notice that in our example Tom is actually better than Hank at producing both goods: Tom can catch more fish in a week, and he can also gather more coconuts. That is, Tom has an **absolute advantage** in both activities: he can produce more output with a given amount of input (in this case, his time) than Hank. You might therefore be tempted to think that Tom has nothing to gain from trading with the less competent Hank.

An individual has an **absolute advantage** in an activity if he or she can do it better than other people. Having an absolute advantage is not the same thing as having a comparative advantage.

But we've just seen that Tom can indeed benefit from a deal with Hank because *comparative,* not *absolute,* advantage is the basis for mutual gain. It doesn't matter that it takes Hank more time to gather a coconut; what matters is that for him the opportunity cost of that coconut in terms of fish is lower. So Hank, despite his absolute disadvantage, even in coconuts, has a comparative advantage in coconut-gathering. Meanwhile Tom, who can use his time better by catching fish, has a comparative *dis*advantage in coconut-gathering.

If comparative advantage were relevant only to castaways, it might not be that interesting. In fact, however, the idea of comparative advantage applies to many activities in the economy. Perhaps its most important application is to trade—not between individuals, but between countries. So let's look briefly at how the model of comparative advantage helps in understanding both the causes and the effects of international trade.

Comparative Advantage and International Trade

Look at the label on a manufactured good sold in the United States, and there's a good chance you will find that it was produced in some other country—in China, or Japan, or even in Canada, eh? On the other side, many U.S. industries sell a large fraction of their output overseas. (This is particularly true of agriculture, high technology, and entertainment.)

Should all this international exchange of goods and services be celebrated, or is it cause for concern? Politicians and the public often question the desirability of international trade, arguing that the nation should produce goods for itself rather than buying them from foreigners. Industries around the world demand protection from foreign competition: Japanese farmers want to keep out American rice, American steelworkers want to keep out European steel. And these demands are often supported by public opinion.

Economists, however, have a very positive view of international trade. Why? Because they view it in terms of comparative advantage.

Figure 2-6 on the next page shows, with a simple example, how international trade can be interpreted in terms of comparative advantage. Although the example as constructed is hypothetical, it is based on an actual pattern of international trade: American exports of pork to Canada and Canadian exports of aircraft to the United States. Panels (a) and (b) illustrate hypothetical production possibility frontiers for the United States and Canada, with pork measured on the horizontal axis and aircraft measured on the vertical axis. The U.S. production possibility frontier is flatter than the Canadian frontier, implying that producing one more ton of pork costs a lot fewer aircraft in the United States than it does in Canada. This means that the United States has a comparative advantage in pork and Canada has a comparative advantage in aircraft.

Although the consumption points in Figure 2-6 are hypothetical, they illustrate a general principle: just like the example of Tom and Hank, the United States and Canada can both achieve mutual gains from trade. If the United States concentrates on producing pork and ships some of its output to Canada, while Canada concentrates on aircraft and ships some of its output to the United States, both countries can consume more than if they insisted on being self-sufficient.

PITFALLS

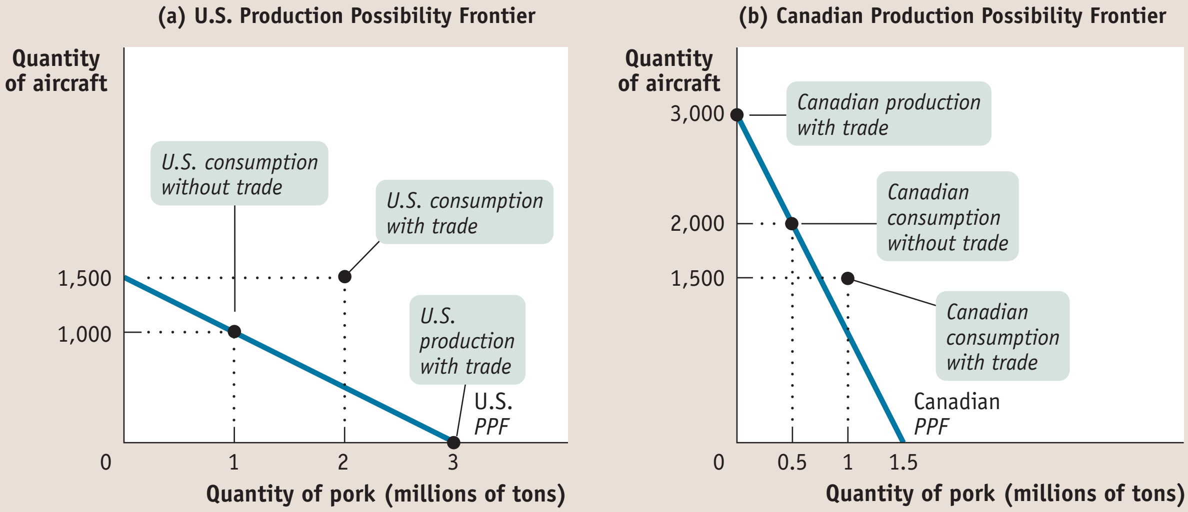
MISUNDERSTANDING COMPARATIVE ADVANTAGE

Students do it, pundits do it, and politicians do it all the time: they confuse *comparative* advantage with *absolute* advantage. For example, back in the 1980s, when the U.S. economy seemed to be lagging behind that of Japan, one often heard commentators warn that if we didn't improve our productivity, we would soon have no comparative advantage in anything.

What those commentators meant was that we would have no *absolute* advantage in anything—that there might come a time when the Japanese were better at everything than we were. (It didn't turn out that way, but that's another story.) And they had the idea that in that case we would no longer be able to benefit from trade with Japan.

But just as Hank is able to benefit from trade with Tom (and vice versa) despite the fact that Tom is better at everything, nations can still gain from trade even if they are less productive in all industries than the countries they trade with.

FIGURE 2-6 Comparative Advantage and International Trade



In this hypothetical example, Canada and the United States produce only two goods: pork and aircraft. Aircraft are measured on the vertical axis and pork on the horizontal axis. Panel (a) shows the U.S. production possibility frontier. It is relatively flat, implying that the United States has a comparative advantage in pork production. Panel (b) shows the Canadian production possibility frontier. It is relatively steep, implying that Canada has a comparative advantage in aircraft production. Just like two individuals, both countries gain from specialization and trade.

Moreover, these mutual gains don't depend on each country being better at producing one kind of good. Even if one country has, say, higher output per person-hour in both industries—that is, even if one country has an absolute advantage in both industries—there are still mutual gains from trade.

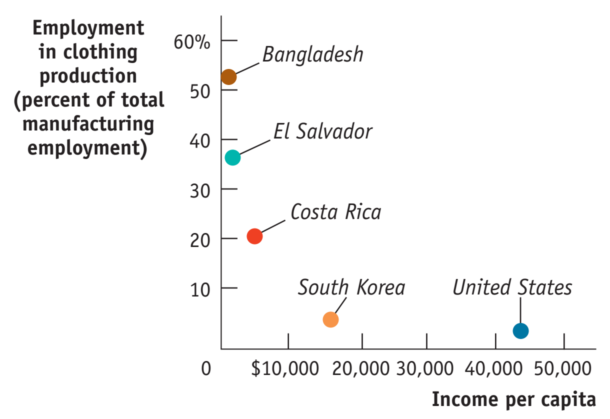
GLOBAL COMPARISON

PAJAMA REPUBLICS

Poor countries tend to have low productivity in clothing manufacture, but even lower productivity in other industries (see the upcoming Economics in Action). As a result, they have a comparative advantage in clothing production, which actually dominates the industries of some very poor countries. An official from one such country once joked, "We are not a banana republic—we are a pajama republic."

This figure, which compares per capita income (the total income of the country divided by the size of the population) with the share of the clothing industry in manufacturing employment, shows just how strong this effect is.

According to a U.S. Department of Commerce assessment, Bangladesh's clothing industry has "low productivity, largely low literacy levels, frequent labor unrest, and outdated technology." Yet it devotes most of its manufacturing workforce to clothing, the sector in which it nonetheless has a *comparative* advantage because its productivity in nonclothing industries is even lower. The same assessment describes Costa Rica as having "relatively high productivity" in clothing—yet a much smaller and declining fraction of Costa Rica's workforce is employed in clothing production. That's because productivity in nonclothing industries is somewhat higher in Costa Rica than in Bangladesh.



Source: World Bank, World Development Indicators; Nicita A. and M. Olarreaga "Trade, Production and Protection 1976–2004," *World Bank Economic Review* 21 no. 1 (2007): 165–171.

Transactions: The Circular-Flow Diagram

The little economy created by Tom and Hank on their island lacks many features of the modern American economy. For one thing, though millions of Americans are self-employed, most workers are employed by someone else, usually a company with hundreds or thousands of employees. Also, Tom and Hank engage only in the simplest of economic transactions, **barter,** in which an individual directly trades a good or service he or she has for a good or service he or she wants. In the modern economy, simple barter is rare: usually people trade goods or services for money—pieces of colored paper with no inherent value—and then trade those pieces of colored paper for the goods or services they want. That is, they sell goods or services and buy other goods or services.

And they both sell and buy a lot of different things. The U.S. economy is a vastly complex entity, with more than a hundred million workers employed by millions of companies, producing millions of different goods and services. Yet you can learn some very important things about the economy by considering the simple graphic shown in Figure 2-7, the **circular-flow diagram.** This diagram represents the transactions that take place in an economy by two kinds of flows around a circle: flows of physical things such as goods, services, labor, or raw materials in one direction, and flows of money that pay for these physical things in the opposite direction. In this case the physical flows are shown in yellow, the money flows in green.

The simplest circular-flow diagram illustrates an economy that contains only two kinds of "inhabitants": **households** and **firms.** A household consists of either an individual or a group of people (usually, but not necessarily, a family) that share their income. A firm is an organization (usually, but not necessarily, a corporation) that produces goods and services for sale—and that employs members of households.

As you can see in Figure 2-7, there are two kinds of markets in this simple economy. On one side (here the left side) there are **markets for goods and services** in which households buy the goods and services they want from firms. This produces a flow of goods and services to households and a return flow of money to firms.

On the other side, there are **factor markets** in which firms buy the resources they need to produce goods and services. Recall from earlier in the chapter that the main factors of production are land, labor, capital, and human capital.

Trade takes the form of **barter** when people directly exchange goods or services that they have for goods or services that they want.

The **circular-flow diagram** represents the transactions in an economy by flows around a circle.

A **household** is a person or a group of people that share their income.

A **firm** is an organization that produces goods and services for sale.

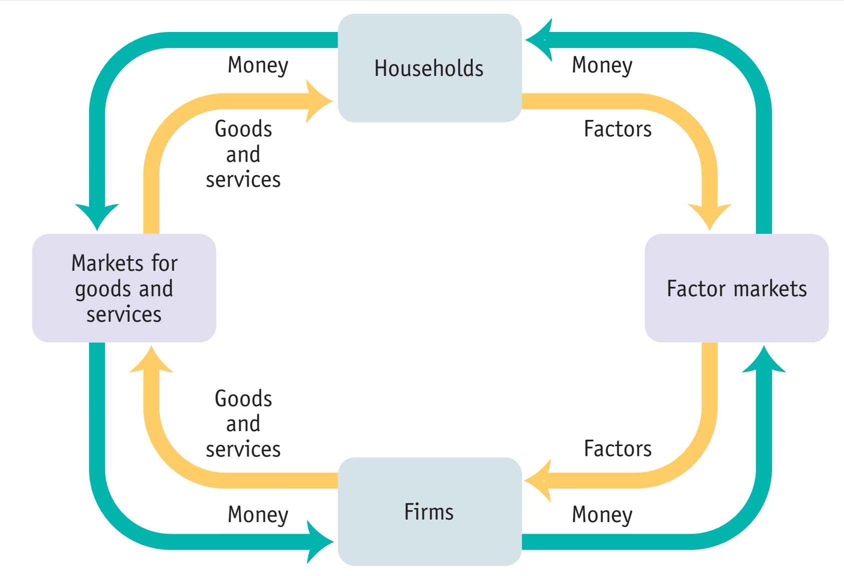
Firms sell goods and services that they produce to households in **markets for goods and services.**

Firms buy the resources they need to produce goods and services in **factor markets.**

FIGURE 2-7

The Circular-Flow Diagram

This diagram represents the flows of money and goods and services in the economy. In the markets for goods and services, households purchase goods and services from firms, generating a flow of money to the firms and a flow of goods and services to the households. The money flows back to households as firms purchase factors of production from the households in factor markets.



An economy's **income distribution** is the way in which total income is divided among the owners of the various factors of production.

The factor market most of us know best is the *labor market*, in which workers are paid for their time. Besides labor, we can think of households as owning and selling the other factors of production to firms. For example, when a corporation pays dividends to its stockholders, who are members of households, it is in effect paying them for the use of the machines and buildings that ultimately belong to those investors. In this case, the transactions are occurring in the *capital market,* the market in which capital is bought and sold. As we'll examine in detail later, factor markets ultimately determine an economy's **income distribution,** how the total income created in an economy is allocated between less skilled workers, highly skilled workers, and the owners of capital and land.

The circular-flow diagram ignores a number of real-world complications in the interests of simplicity. A few examples:

- In the real world, the distinction between firms and households isn't always that clear-cut. Consider a small, family-run business—a farm, a shop, a small hotel. Is this a firm or a household? A more complete picture would include a separate box for family businesses.
- Many of the sales firms make are not to households but to other firms; for example, steel companies sell mainly to other companies such as auto manufacturers, not to households. A more complete picture would include these flows of goods, services, and money within the business sector.
- The figure doesn't show the government, which in the real world diverts quite a lot of money out of the circular flow in the form of taxes but also injects a lot of money back into the flow in the form of spending.

Figure 2-7, in other words, is by no means a complete picture either of all the types of inhabitants of the real economy or of all the flows of money and physical items that take place among these inhabitants.

Despite its simplicity, the circular-flow diagram is a very useful aid to thinking about the economy.

➤ECONOMICS IN ACTION

Rich Nation, Poor Nation

Try taking off your clothes—at a suitable time and in a suitable place, of course—and take a look at the labels inside that say where they were made. It's a very good bet that much, if not most, of your clothing was manufactured overseas, in a country that is much poorer than the United States—say, in El Salvador, Sri Lanka, or Bangladesh.

Why are these countries so much poorer than we are? The immediate reason is that their economies are much less *productive*—firms in these countries are just not able to produce as much from a given quantity of resources as comparable firms in the United States or other wealthy countries. Why countries differ so much in productivity is a deep question—indeed, one of the main questions that preoccupy economists. But in any case, the difference in productivity is a fact.

Robert Nickelsberg/Getty Images

Although less productive than American workers, Bangladeshi workers have a comparative advantage in clothing production.

But if the economies of these countries are so much less productive than ours, how is it that they make so much of our clothing? Why don't we do it for ourselves?

The answer is "comparative advantage." Just about every industry in Bangladesh is much less productive than the corresponding industry in the United States. But the productivity difference between rich and poor countries varies across goods; it is very large in the production of sophisticated goods like aircraft but not that large in the production of simpler goods like clothing. So Bangladesh's position with regard to clothing production is like Hank's position with respect to coconut-gathering: he's not as good at it as his fellow castaway, but it's the thing he does comparatively well.

Bangladesh, though it is at an absolute disadvantage compared with the United States in almost everything, has a comparative advantage in clothing production. This means that both the United States and Bangladesh are able to consume more because they specialize in producing different things, with Bangladesh supplying our clothing and the United States supplying Bangladesh with more sophisticated goods. ▲

QUICK REVIEW

- Most economic **models** are "thought experiments" or simplified representations of reality, which rely on the **other things equal assumption.**
- An important economic model is the **production possibility frontier,** which illustrates the concepts of efficiency, opportunity cost, and economic growth.
- **Comparative advantage** is a model that explains the source of gains from trade but is often confused with **absolute advantage.** Every person and every country has a comparative advantage in something, giving rise to gains from trade.
- In the simplest economies people **barter** rather than trade with money as in a modern economy. The **circular-flow diagram** illustrates transactions within the economy as flows of goods and services, **factors of production,** and money between **households** and **firms.** These transactions occur in **markets for goods and services** and **factor markets.** Ultimately, factor markets determine the economy's **income distribution,** how total income is divided among the owners of the various factors of production.

CHECK YOUR UNDERSTANDING 2-1

1. True or false? Explain your answer.
   a. An increase in the amount of resources available to Tom for use in producing coconuts and fish does not change his production possibility frontier.
   b. A technological change that allows Tom to catch more fish for any amount of coconuts gathered results in a change in his production possibility frontier.
   c. The production possibility frontier is useful because it illustrates how much of one good an economy must give up to get more of another good regardless of whether resources are being used efficiently.
2. In Italy, an automobile can be produced by 8 workers in one day and a washing machine by 3 workers in one day. In the United States, an automobile can be produced by 6 workers in one day, and a washing machine by 2 workers in one day.
   a. Which country has an absolute advantage in the production of automobiles? In washing machines?
   b. Which country has a comparative advantage in the production of washing machines? In automobiles?
   c. What pattern of specialization results in the greatest gains from trade between the two countries?
3. Explain why Tom and Hank are willing to engage in a trade of 1 fish for 1.5 coconuts.
4. Use the circular-flow diagram to explain how an increase in the amount of money spent by households results in an increase in the number of jobs in the economy. Describe in words what the circular-flow diagram predicts.

Solutions appear at back of book.

Using Models

Economics, we have now learned, is mainly a matter of creating models that draw on a set of basic principles but add some more specific assumptions that allow the modeler to apply those principles to a particular situation. But what do economists actually *do* with their models?

Positive versus Normative Economics

Imagine that you are an economic adviser to the governor of your state. What kinds of questions might the governor ask you to answer?

Well, here are three possible questions:

1. How much revenue will the tolls on the state turnpike yield next year?
2. How much would that revenue increase if the toll were raised from $1 to $1.50?
3. Should the toll be raised, bearing in mind that a toll increase will reduce traffic and air pollution near the road but will impose some financial hardship on frequent commuters?

There is a big difference between the first two questions and the third one. The first two are questions about facts. Your forecast of next year's toll collection will be proved right or wrong when the numbers actually come in. Your estimate of the impact of a change in the toll is a little harder to check—revenue depends on other factors besides the toll, and it may be hard to disentangle the causes of any change in revenue. Still, in principle there is only one right answer.

Positive economics is the branch of economic analysis that describes the way the economy actually works.

Normative economics makes prescriptions about the way the economy should work.

A **forecast** is a simple prediction of the future.

But the question of whether tolls should be raised may not have a "right" answer—two people who agree on the effects of a higher toll could still disagree about whether raising the toll is a good idea. For example, someone who lives near the turnpike but doesn't commute on it will care a lot about noise and air pollution but not so much about commuting costs. A regular commuter who doesn't live near the turnpike will have the opposite priorities.

This example highlights a key distinction between two roles of economic analysis. Analysis that tries to answer questions about the way the world works, which have definite right and wrong answers, is known as **positive economics.** In contrast, analysis that involves saying how the world *should* work is known as **normative economics.** To put it another way, positive economics is about description, normative economics is about prescription.

Positive economics occupies most of the time and effort of the economics profession. And models play a crucial role in almost all positive economics. As we mentioned earlier, the U.S. government uses a computer model to assess proposed changes in national tax policy, and many state governments have similar models to assess the effects of their own tax policy.

It's worth noting that there is a subtle but important difference between the first and second questions we imagined the governor asking. Question 1 asked for a simple prediction about next year's revenue—a **forecast.** Question 2 was a "what if" question, asking how revenue would change if the tax law were to change. Economists are often called upon to answer both types of questions, but models are especially useful for answering "what if" questions.

The answers to such questions often serve as a guide to policy, but they are still predictions, not prescriptions. That is, they tell you what will happen if a policy is changed; they don't tell you whether or not that result is good. Suppose that your economic model tells you that the governor's proposed increase in highway tolls will raise property values in communities near the road but will hurt people who must use the turnpike to get to work. Does that make this proposed toll increase a good idea or a bad one? It depends on whom you ask. As we've just seen, someone who is very concerned with the communities near the road will support the increase, but someone who is very concerned with the welfare of drivers will feel differently. That's a value judgment—it's not a question of economic analysis.

Still, economists often do engage in normative economics and give policy advice. How can they do this when there may be no "right" answer?

One answer is that economists are also citizens, and we all have our opinions. But economic analysis can often be used to show that some policies are clearly better than others, regardless of anyone's opinions.

Suppose that policies A and B achieve the same goal, but policy A makes everyone better off than policy B—or at least makes some people better off without making other people worse off. Then A is clearly more efficient than B. That's not a value judgment: we're talking about how best to achieve a goal, not about the goal itself.

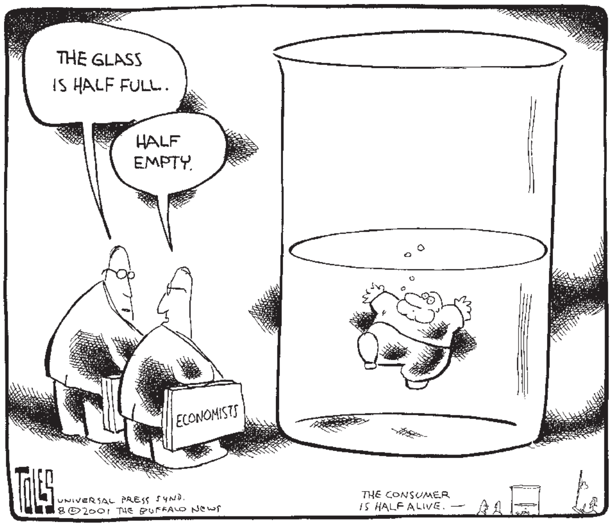
For example, two different policies have been used to help low-income families obtain housing: rent control, which limits the rents landlords are allowed to charge, and rent subsidies, which provide families with additional money to pay rent. Almost all economists agree that subsidies are the more efficient policy. (In Chapter 5 we'll see why this is so.) And so the great majority of economists, whatever their personal politics, favor subsidies over rent control.

When policies can be clearly ranked in this way, then economists generally agree. But it is no secret that economists sometimes disagree.

When and Why Economists Disagree

Economists have a reputation for arguing with each other. Where does this reputation come from?

One important answer is that media coverage tends to exaggerate the real differences in views among economists. If nearly all economists agree on an issue—for



example, the proposition that rent controls lead to housing shortages—reporters and editors are likely to conclude that there is no story worth covering, and so the professional consensus tends to go unreported. But when there is some issue on which prominent economists take opposing sides on the same issue—for example, whether cutting taxes right now would help the economy—that does make a good news story. So you hear much more about the areas of disagreement within economics than you do about the large areas of agreement.

It is also worth remembering that economics is, unavoidably, often tied up in politics. On a number of issues powerful interest groups know what opinions they want to hear; they therefore have an incentive to find and promote economists who profess those opinions, giving these economists a prominence and visibility out of proportion to their support among their colleagues.

But although the appearance of disagreement among economists exceeds the reality, it remains true that economists often *do* disagree about important things. For example, some very respected economists argue vehemently that the U.S. government should replace the income tax with a *value-added tax* (a national sales tax, which is the main source of government revenue in many European countries). Other equally respected economists disagree. Why this difference of opinion?

One important source of differences is in values: as in any diverse group of individuals, reasonable people can differ. In comparison to an income tax, a value-added tax typically falls more heavily on people of modest means. So an economist who values a society with more social and income equality for its own sake will tend to oppose a value-added tax. An economist with different values will be less likely to oppose it.

A second important source of differences arises from economic modeling. Because economists base their conclusions on models, which are simplified representations of reality, two economists can legitimately disagree about which simplifications are appropriate—and therefore arrive at different conclusions.

Suppose that the U.S. government was considering introducing a value-added tax. Economist A may rely on a model that focuses on the administrative costs of tax systems—that is, the costs of monitoring, processing papers, collecting the tax, and so on. This economist might then point to the well-known high costs of administering a value-added tax and argue against the change. But economist B may think that the right way to approach the question is to ignore the administrative costs and focus on how the proposed law would change savings behavior. This economist might point to studies suggesting that value-added taxes promote higher consumer saving, a desirable result.

FOR INQUIRING MINDS

When Economists Agree

"If all the economists in the world were laid end to end, they still couldn't reach a conclusion." So goes one popular economist joke. But do economists really disagree that much?

Not according to a classic survey of members of the American Economic Association, reported in the May 1992 issue of the *American Economic Review*. The authors asked respondents to agree or disagree with a number of statements about the economy; what they found was a high level of agreement among professional economists on many of the statements. At the top, with more than 90 percent of the economists agreeing, were "Tariffs and import quotas usually reduce general economic welfare" and "A ceiling on rents reduces the quantity and quality of housing available." What's striking about these two statements is that many noneconomists disagree: tariffs and import quotas to keep out foreign-produced goods are favored by many voters, and proposals to do away with rent control in cities like New York and San Francisco have met fierce political opposition.

So is the stereotype of quarreling economists a myth? Not entirely: economists do disagree quite a lot on some issues, especially in macroeconomics. But there is a large area of common ground.

Because the economists have used different models—that is, made different simplifying assumptions—they arrive at different conclusions. And so the two economists may find themselves on different sides of the issue.

Most such disputes are eventually resolved by the accumulation of evidence showing which of the various models proposed by economists does a better job of fitting the facts. However, in economics, as in any science, it can take a long time before research settles important disputes—decades, in some cases. And since the economy is always changing, in ways that make old models invalid or raise new policy questions, there are always new issues on which economists disagree. The policy maker must then decide which economist to believe.

The important point is that economic analysis is a method, not a set of conclusions.

➤ECONOMICS IN ACTION

Economists in Government

Many economists are mainly engaged in teaching and research. But quite a few economists have a more direct hand in events.

As described earlier in the chapter (For Inquiring Minds, "Models for Money"), economists play a significant role in the business world, especially in the financial industry. But the most striking involvement of economists in the "real" world is their extensive participation in government.

This shouldn't be surprising: one of the most important functions of government is to make economic policy, and almost every government policy decision must take economic effects into consideration. So governments around the world employ economists in a variety of roles.

In the U.S. government, a key role is played by the Council of Economic Advisers, a branch of the Executive Office (that is, the staff of the President) whose sole purpose is to advise the White House on economic matters and to prepare the annual Economic Report of the President. Unlike most employees in government agencies, the majority of the economists at the Council are not long-term civil servants; instead, they are mainly professors on leave for one or two years from their universities. Many of the nation's best-known economists have served on the Council of Economic Advisers at some point during their careers.

Economists also play an important role in many other parts of the U.S. government. Indeed, as the Bureau of Labor Statistics *Occupational Outlook Handbook* says, "Government employed 58 percent of economists in a wide range of government agencies." Needless to say, the Bureau of Labor Statistics is itself a major employer of economists. And economists dominate the staff of the Federal Reserve, a government agency that controls the supply of money in the economy and is crucial to its operation.

It's also worth noting that economists play an especially important role in two international organizations headquartered in Washington, D.C.: the International Monetary Fund, which provides advice and loans to countries experiencing economic difficulties, and the World Bank, which provides advice and loans to promote long-term economic development.

Do all these economists in government disagree with each other all the time? Are their positions largely dictated by political affiliation? The answer to both questions is no. Although there are important disputes over economic issues in government, and politics inevitably plays some role, there is broad agreement among economists on many issues, and most economists in government try very hard to assess issues as objectively as possible. ▲

>> QUICK REVIEW

- Economists do mostly **positive economics,** analysis of the way the world works, in which there are definite right and wrong answers and which involve making **forecasts.** But in **normative economics,** which makes prescriptions about how things ought to be, there are often no right answers and only value judgments.
- Economists do disagree—though not as much as legend has it—for two main reasons. One, they may disagree about which simplifications to make in a model. Two, economists may disagree—like everyone else—about values.

➤ CHECK YOUR UNDERSTANDING 2-2

1. Which of the following statements is a positive statement? Which is a normative statement?
   a. Society should take measures to prevent people from engaging in dangerous personal behavior.
   b. People who engage in dangerous personal behavior impose higher costs on society through higher medical costs.
2. True or false? Explain your answer.
   a. Policy choice A and policy choice B attempt to achieve the same social goal. Policy choice A, however, results in a much less efficient use of resources than policy choice B. Therefore, economists are more likely to agree on choosing policy choice B.
   b. When two economists disagree on the desirability of a policy, it's typically because one of them has made a mistake.
   c. Policy makers can always use economics to figure out which goals a society should try to achieve.

Solutions appear at back of book.

>> A LOOK AHEAD •••

This chapter has given you a first view of what it means to do economics, starting with the general idea of models as a way to make sense of a complicated world and then moving on to two simple introductory models.

To get a real sense of how economic analysis works, however, and to show just how useful such analysis can be, we need to move on to a more powerful model. In the next two chapters we will study the quintessential economic model, one that has an amazing ability to make sense of many policy issues, predict the effects of many forces, and change the way you look at the world. That model is known as "supply and demand."

SUMMARY

1. Almost all economics is based on **models,** "thought experiments" or simplified versions of reality, many of which use mathematical tools such as graphs. An important assumption in economic models is the **other things equal assumption,** which allows analysis of the effect of a change in one factor by holding all other relevant factors unchanged.
2. One important economic model is the **production possibility frontier.** It illustrates: *opportunity cost* (showing how much less of one good can be produced if more of the other good is produced); *efficiency* (an economy is efficient in production if it produces on the production possibility frontier and efficient in allocation if it produces the mix of goods and services that people want to consume); and *economic growth* (an outward shift of the production possibility frontier). There are two basic sources of growth: an increase in **factors of production,** resources such as land, labor, capital, and human capital, inputs that are not used up in production, and improved **technology.**
3. Another important model is **comparative advantage,** which explains the source of gains from trade between individuals and countries. Everyone has a comparative advantage in something—some good or service in which that person has a lower opportunity cost than everyone else. But it is often confused with **absolute advantage,** an ability to produce a particular good or service better than anyone else. This confusion leads some to erroneously conclude that there are no gains from trade between people or countries.
4. In the simplest economies people **barter**—trade goods and services for one another—rather than trade them for money, as in a modern economy. The **circular-flow diagram** represents transactions within the economy as flows of goods, services, and money between **households** and **firms.** These transactions occur in **markets for goods and services** and **factor markets,** markets for **factors of production**—land, labor, capital, and human capital. It is useful in understanding how spending, production, employment, income, and growth are related in the economy. Ultimately, factor markets determine the economy's **income distribution,** how an economy's total income is allocated to the owners of the factors of production.
5. Economists use economic models for both **positive economics,** which describes how the economy works, and for **normative economics,** which prescribes how the economy *should* work. Positive economics often involves making **forecasts.** Economists can determine correct answers for positive questions, but typically not

for normative questions, which involve value judgments. The exceptions are when policies designed to achieve a certain prescription can be clearly ranked in terms of efficiency.

6. There are two main reasons economists disagree. One, they may disagree about which simplifications to make in a model. Two, economists may disagree—like everyone else—about values.

KEY TERMS

Model, p. 24
Other things equal assumption, p. 24
Production possibility frontier, p. 25
Factors of production, p. 29
Technology, p. 29
Comparative advantage, p. 31
Absolute advantage, p. 33
Barter, p. 35
Circular-flow diagram, p. 35
Household, p. 35
Firm, p. 35
Markets for goods and services, p. 35
Factor markets, p. 35
Income distribution, p. 36
Positive economics, p. 38
Normative economics, p. 38
Forecast, p. 38

PROBLEMS

1. Two important industries on the island of Bermuda are fishing and tourism. According to data from the World Resources Institute and the Bermuda Department of Statistics, in the year 2000 the 307 registered fishermen in Bermuda caught 286 metric tons of marine fish. And the 3,409 people employed by hotels produced 538,000 hotel stays (measured by the number of visitor arrivals). Suppose that this production point is efficient in production. Assume also that the opportunity cost of one additional metric ton of fish is 2,000 hotel stays and that this opportunity cost is constant (the opportunity cost does not change).
   - **a.** If all 307 registered fishermen were to be employed by hotels (in addition to the 3,409 people already working in hotels), how many hotel stays could Bermuda produce?
   - **b.** If all 3,409 hotel employees were to become fishermen (in addition to the 307 fishermen already working in the fishing industry), how many metric tons of fish could Bermuda produce?
   - **c.** Draw a production possibility frontier for Bermuda, with fish on the horizontal axis and hotel stays on the vertical axis, and label Bermuda's actual production point for the year 2000.

2. Atlantis is a small, isolated island in the South Atlantic. The inhabitants grow potatoes and catch fish. The accompanying table shows the maximum annual output combinations of potatoes and fish that can be produced. Obviously, given their limited resources and available technology, as they use more of their resources for potato production, there are fewer resources available for catching fish.

Maximum annual output options	Quantity of potatoes (pounds)	Quantity of fish (pounds)
A	1,000	0
B	800	300
C	600	500
D	400	600
E	200	650
F	0	675

   - **a.** Draw a production possibility frontier with potatoes on the horizontal axis and fish on the vertical axis illustrating these options, showing points *A–F*.
   - **b.** Can Atlantis produce 500 pounds of fish and 800 pounds of potatoes? Explain. Where would this point lie relative to the production possibility frontier?
   - **c.** What is the opportunity cost of increasing the annual output of potatoes from 600 to 800 pounds?
   - **d.** What is the opportunity cost of increasing the annual output of potatoes from 200 to 400 pounds?
   - **e.** Can you explain why the answers to parts c and d are not the same? What does this imply about the slope of the production possibility frontier?

3. According to data from the U.S. Department of Agriculture's National Agricultural Statistics Service, 124 million acres of land in the United States were used for wheat or corn farming in 2004. Of those 124 million acres, farmers used 50 million acres to grow 2.158 billion bushels of wheat and 74 million acres of land to grow 11.807 billion bushels of corn. Suppose that U.S. wheat and corn farming is efficient in production. At that production point, the opportunity cost of producing one additional bushel of wheat is 1.7 fewer bushels of corn. However, farmers have increasing opportunity costs, so that additional bushels of wheat have an opportunity cost greater than 1.7 bushels of corn. For each of the following production points, decide whether that production point is (i) feasible and efficient in production, (ii) feasible but not efficient in production, (iii) not feasible, or (iv) unclear as to whether or not it is feasible.
   - **a.** Farmers use 40 million acres of land to produce 1.8 billion bushels of wheat, and they use 60 million acres of land to produce 9 billion bushels of corn. The remaining 24 million acres are left unused.
   - **b.** From their original production point, farmers transfer 40 million acres of land from corn to wheat production. They now produce 3.158 billion bushels of wheat and 10.107 bushels of corn.
   - **c.** Farmers reduce their production of wheat to 2 billion bushels and increase their production of corn to 12.044

billion bushels. Along the production possibility frontier, the opportunity cost of going from 11.807 billion bushels of corn to 12.044 billion bushels of corn is 0.666 bushel of wheat per bushel of corn.

4. In the ancient country of Roma, only two goods, spaghetti and meatballs, are produced. There are two tribes in Roma, the Tivoli and the Frivoli. By themselves, the Tivoli each month can produce either 30 pounds of spaghetti and no meatballs, or 50 pounds of meatballs and no spaghetti, or any combination in between. The Frivoli, by themselves, each month can produce 40 pounds of spaghetti and no meatballs, or 30 pounds of meatballs and no spaghetti, or any combination in between.

a. Assume that all production possibility frontiers are straight lines. Draw one diagram showing the monthly production possibility frontier for the Tivoli and another showing the monthly production possibility frontier for the Frivoli. Show how you calculated them.

b. Which tribe has the comparative advantage in spaghetti production? In meatball production?

In A.D. 100 the Frivoli discover a new technique for making meatballs that doubles the quantity of meatballs they can produce each month.

c. Draw the new monthly production possibility frontier for the Frivoli.

d. After the innovation, which tribe now has an absolute advantage in producing meatballs? In producing spaghetti? Which has the comparative advantage in meatball production? In spaghetti production?

5. According to the U.S. Census Bureau, in July 2006 the United States exported aircraft worth $1 billion to China and imported aircraft worth only $19,000 from China. During the same month, however, the United States imported $83 million worth of men's trousers, slacks, and jeans from China but exported only $8,000 worth of trousers, slacks, and jeans to China. Using what you have learned about how trade is determined by comparative advantage, answer the following questions.

a. Which country has the comparative advantage in aircraft production? In production of trousers, slacks, and jeans?

b. Can you determine which country has the absolute advantage in aircraft production? In production of trousers, slacks, and jeans?

6. Peter Pundit, an economics reporter, states that the European Union (EU) is increasing its productivity very rapidly in all industries. He claims that this productivity advance is so rapid that output from the EU in these industries will soon exceed that of the United States and, as a result, the United States will no longer benefit from trade with the EU.

a. Do you think Peter Pundit is correct or not? If not, what do you think is the source of his mistake?

b. If the EU and the United States continue to trade, what do you think will characterize the goods that the EU exports to the United States and the goods that the United States exports to the EU?

7. You are in charge of allocating residents to your dormitory's baseball and basketball teams. You are down to the last four people, two of whom must be allocated to baseball and two to basketball. The accompanying table gives each person's batting average and free-throw average.

Name	Batting average	Free-throw average
Kelley	70%	60%
Jackie	50%	50%
Curt	10%	30%
Gerry	80%	70%

a. Explain how you would use the concept of comparative advantage to allocate the players. Begin by establishing each player's opportunity cost of free throws in terms of batting average.

b. Why is it likely that the other basketball players will be unhappy about this arrangement but the other baseball players will be satisfied? Nonetheless, why would an economist say that this is an efficient way to allocate players for your dormitory's sports teams?

8. The inhabitants of the fictional economy of Atlantis use money in the form of cowry shells. Draw a circular-flow diagram showing households and firms. Firms produce potatoes and fish, and households buy potatoes and fish. Households also provide the land and labor to firms. Identify where in the flows of cowry shells or physical things (goods and services, or resources) each of the following impacts would occur. Describe how this impact spreads around the circle.

a. A devastating hurricane floods many of the potato fields.

b. A very productive fishing season yields a very large number of fish caught.

c. The inhabitants of Atlantis discover Shakira and spend several days a month at dancing festivals.

9. An economist might say that colleges and universities "produce" education, using faculty members and students as inputs. According to this line of reasoning, education is then "consumed" by households. Construct a circular-flow diagram to represent the sector of the economy devoted to college education: colleges and universities represent firms, and households both consume education and provide faculty and students to universities. What are the relevant markets in this diagram? What is being bought and sold in each direction? What would happen in the diagram if the government decided to subsidize 50% of all college students' tuition?

10. Your dormitory roommate plays loud music most of the time; you, however, would prefer more peace and quiet. You suggest that she buy some earphones. She responds that although she would be happy to use earphones, she has many other things that she would prefer to spend her money on right now. You discuss this situation with a friend who is an economics major. The following exchange takes place:

He: How much would it cost to buy earphones?

You: $15.

He: How much do you value having some peace and quiet for the rest of the semester?
You: $30.
He: It is efficient for you to buy the earphones and give them to your roommate. You gain more than you lose; the benefit exceeds the cost. You should do that.
You: It just isn't fair that I have to pay for the earphones when I'm not the one making the noise.

a. Which parts of this conversation contain positive statements and which parts contain normative statements?

b. Compose an argument supporting your viewpoint that your roommate should be the one to change her behavior. Similarly, compose an argument from the viewpoint of your roommate that you should be the one to buy the earphones. If your dormitory has a policy that gives residents the unlimited right to play music, whose argument is likely to win? If your dormitory has a rule that a person must stop playing music whenever a roommate complains, whose argument is likely to win?

11. A representative of the American clothing industry recently made the following statement: "Workers in Asia often work in sweatshop conditions earning only pennies an hour. American workers are more productive and as a result earn higher wages. In order to preserve the dignity of the American workplace, the government should enact legislation banning imports of low-wage Asian clothing."

a. Which parts of this quote are positive statements? Which parts are normative statements?

b. Is the policy that is being advocated consistent with the preceding statements about the wages and productivities of American and Asian workers?

c. Would such a policy make some Americans better off without making any other Americans worse off? That is, would this policy be efficient from the viewpoint of all Americans?

d. Would low-wage Asian workers benefit from or be hurt by such a policy?

12. Are the following statements true or false? Explain your answers.

a. "When people must pay higher taxes on their wage earnings, it reduces their incentive to work" is a positive statement.

b. "We should lower taxes to encourage more work" is a positive statement.

c. Economics cannot always be used to completely decide what society ought to do.

d. "The system of public education in this country generates greater benefits to society than the cost of running the system" is a normative statement.

e. All disagreements among economists are generated by the media.

13. Evaluate the following statement: "It is easier to build an economic model that accurately reflects events that have already occurred than to build an economic model to forecast future events." Do you think that this is true or not? Why? What does this imply about the difficulties of building good economic models?

14. Economists who work for the government are often called on to make policy recommendations. Why do you think it is important for the public to be able to differentiate normative statements from positive statements in these recommendations?

15. The mayor of Gotham City, worried about a potential epidemic of deadly influenza this winter, asks an economic adviser the following series of questions. Determine whether a question requires the economic adviser to make a positive assessment or a normative assessment.

a. How much vaccine will be in stock in the city by the end of November?

b. If we offer to pay 10% more per dose to the pharmaceutical companies providing the vaccines, will they provide additional doses?

c. If there is a shortage of vaccine in the city, whom should we vaccinate first—the elderly or the very young? (Assume that a person from one group has an equal likelihood of dying from influenza as a person from the other group.)

d. If the city charges $25 per shot, how many people will pay?

e. If the city charges $25 per shot, it will make a profit of $10 per shot, money that can go to pay for inoculating poor people. Should the city engage in such a scheme?

16. Assess the following statement: "If economists just had enough data, they could solve all policy questions in a way that maximizes the social good. There would be no need for divisive political debates, such as whether the government should provide free medical care for all."

>> Chapter 2 Appendix: Graphs in Economics

Getting the Picture

Whether you're reading about economics in the *Wall Street Journal* or in your economics textbook, you will see many graphs. Visual images can make it much easier to understand verbal descriptions, numerical information, or ideas. In economics, graphs are the type of visual image used to facilitate understanding. To fully understand the ideas and information being discussed, you need to be familiar with how to interpret these visual aids. This appendix explains how graphs are constructed and interpreted and how they are used in economics.

A quantity that can take on more than one value is called a **variable.**

Graphs, Variables, and Economic Models

One reason to attend college is that a bachelor's degree provides access to higher-paying jobs. Additional degrees, such as MBAs or law degrees, increase earnings even more. If you were to read an article about the relationship between educational attainment and income, you would probably see a graph showing the income levels for workers with different amounts of education. And this graph would depict the idea that, in general, more education increases income. This graph, like most of those in economics, would depict the relationship between two economic variables. A **variable** is a quantity that can take on more than one value, such as the number of years of education a person has, the price of a can of soda, or a household's income.

As you learned in this chapter, economic analysis relies heavily on *models*, simplified descriptions of real situations. Most economic models describe the relationship between two variables, simplified by holding constant other variables that may affect the relationship. For example, an economic model might describe the relationship between the price of a can of soda and the number of cans of soda that consumers will buy, assuming that everything else that affects consumers' purchases of soda stays constant. This type of model can be described mathematically or verbally, but illustrating the relationship in a graph makes it easier to understand. Next we show how graphs that depict economic models are constructed and interpreted.

How Graphs Work

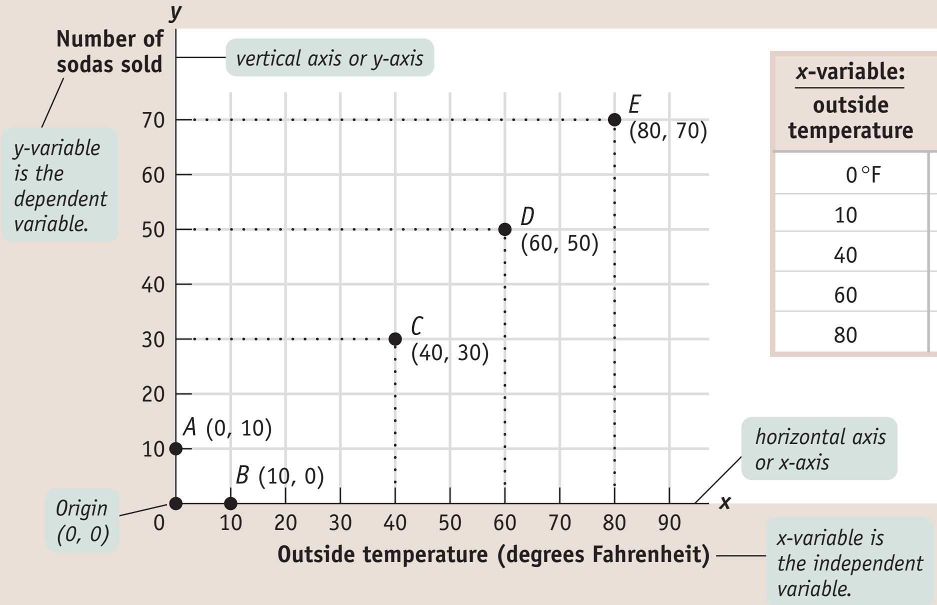
Most graphs in economics are based on a grid built around two perpendicular lines that show the values of two variables, helping you visualize the relationship between them. So a first step in understanding the use of such graphs is to see how this system works.

Two-Variable Graphs

Figure 2A-1 on the next page shows a typical two-variable graph. It illustrates the data in the accompanying table on outside temperature and the number of sodas a typical vendor can expect to sell at a baseball stadium during one game. The first column shows the values of outside temperature (the first variable) and the second column shows the values of the number of sodas sold (the second variable). Five combinations or pairs of the two variables are shown, each denoted by *A* through *E* in the third column.

Now let's turn to graphing the data in this table. In any two-variable graph, one variable is called the *x*-variable and the other is called the *y*-variable. Here we have made outside temperature the *x*-variable and number of sodas sold the *y*-variable. The

FIGURE 2A-1 Plotting Points on a Two-Variable Graph



x-variable: outside temperature	*y*-variable: number of sodas sold	Point
0°F	10	*A*
10	0	*B*
40	30	*C*
60	50	*D*
80	70	*E*

The data from the table are plotted where outside temperature (the independent variable) is measured along the horizontal axis and number of sodas sold (the dependent variable) is measured along the vertical axis. Each of the five combinations of temperature and sodas sold is represented by a point: *A, B, C, D,* and *E*. Each point in the graph is identified by a pair of values. For example, point *C* corresponds to the pair (40, 30)—an outside temperature of 40°F (the value of the *x*-variable) and 30 sodas sold (the value of the *y*-variable).

solid horizontal line in the graph is called the **horizontal axis** or ***x*-axis,** and values of the *x*-variable—outside temperature—are measured along it. Similarly, the solid vertical line in the graph is called the **vertical axis** or ***y*-axis,** and values of the *y*-variable—number of sodas sold—are measured along it. At the **origin,** the point where the two axes meet, each variable is equal to zero. As you move rightward from the origin along the *x*-axis, values of the *x*-variable are positive and increasing. As you move up from the origin along the *y*-axis, values of the *y*-variable are positive and increasing.

You can plot each of the five points *A* through *E* on this graph by using a pair of numbers—the values that the *x*-variable and the *y*-variable take on for a given point. In Figure 2A-1, at point *C*, the *x*-variable takes on the value 40 and the *y*-variable takes on the value 30. You plot point *C* by drawing a line straight up from 40 on the *x*-axis and a horizontal line across from 30 on the *y*-axis. We write point *C* as (40, 30). We write the origin as (0, 0).

Looking at point *A* and point *B* in Figure 2A-1, you can see that when one of the variables for a point has a value of zero, it will lie on one of the axes. If the value of the *x*-variable is zero, the point will lie on the vertical axis, like point *A*. If the value of the *y*-variable is zero, the point will lie on the horizontal axis, like point *B*.

Most graphs that depict relationships between two economic variables represent a **causal relationship,** a relationship in which the value taken by one variable directly influences or determines the value taken by the other variable. In a causal relationship, the determining variable is called the **independent variable;** the variable it determines is called the **dependent variable.** In our example of soda sales, the outside temperature is the independent variable. It directly influences the number of sodas that are sold, the dependent variable in this case.

The line along which values of the *x*-variable are measured is called the **horizontal axis** or ***x*-axis.** The line along which values of the *y*-variable are measured is called the **vertical axis** or ***y*-axis.** The point where the axes of a two-variable graph meet is the **origin.**

A **causal relationship** exists between two variables when the value taken by one variable directly influences or determines the value taken by the other variable. In a causal relationship, the determining variable is called the **independent variable**; the variable it determines is called the **dependent variable.**

By convention, we put the independent variable on the horizontal axis and the dependent variable on the vertical axis. Figure 2A-1 is constructed consistent with this convention; the independent variable (outside temperature) is on the horizontal axis and the dependent variable (number of sodas sold) is on the vertical axis. An important exception to this convention is in graphs showing the economic relationship between the price of a product and quantity of the product: although price is generally the independent variable that determines quantity, it is always measured on the vertical axis.

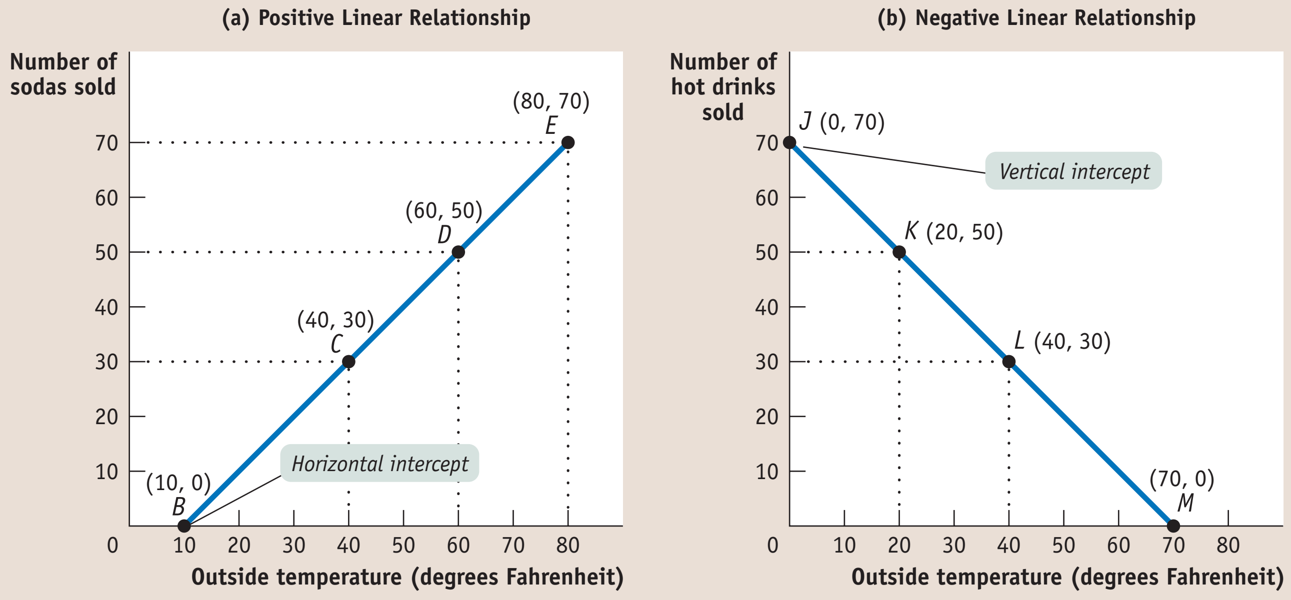
A **curve** is a line on a graph that depicts a relationship between two variables. It may be either a straight line or a curved line. If the curve is a straight line, the variables have a **linear relationship.** If the curve is not a straight line, the variables have a **nonlinear relationship.**

Curves on a Graph

Panel (a) of Figure 2A-2 contains some of the same information as Figure 2A-1, with a line drawn through the points *B, C, D,* and *E.* Such a line on a graph is called a **curve,** regardless of whether it is a straight line or a curved line. If the curve that shows the relationship between two variables is a straight line, or linear, the variables have a **linear relationship.** When the curve is not a straight line, or nonlinear, the variables have a **nonlinear relationship.**

A point on a curve indicates the value of the *y*-variable for a specific value of the *x*-variable. For example, point *D* indicates that at a temperature of 60°F, a vendor can expect to sell 50 sodas. The shape and orientation of a curve reveal the general nature of the relationship between the two variables. The upward tilt of the curve in panel (a) of Figure 2A-2 suggests that vendors can expect to sell more sodas at higher outside temperatures.

FIGURE 2A-2 **Drawing Curves**



The curve in panel (a) illustrates the relationship between the two variables, outside temperature and number of sodas sold. The two variables have a positive linear relationship: positive because the curve has an upward tilt, and linear because it is a straight line. It implies that an increase in the *x*-variable (outside temperature) leads to an increase in the *y*-variable (number of sodas sold). The curve in panel (b) is also a straight line, but it tilts downward. The two variables here, outside temperature and number of hot drinks sold, have a negative linear relationship: an increase in the *x*-variable (outside temperature) leads to a decrease in the *y*-variable (number of hot drinks sold). The curve in panel (a) has a horizontal intercept at point *B,* where it hits the horizontal axis. The curve in panel (b) has a vertical intercept at point *J,* where it hits the vertical axis, and a horizontal intercept at point *M,* where it hits the horizontal axis.

Two variables have a **positive relationship** when an increase in the value of one variable is associated with an increase in the value of the other variable. It is illustrated by a curve that slopes upward from left to right.

Two variables have a **negative relationship** when an increase in the value of one variable is associated with a decrease in the value of the other variable. It is illustrated by a curve that slopes downward from left to right.

The **horizontal intercept** of a curve is the point at which it hits the horizontal axis; it indicates the value of the *x*-variable when the value of the *y*-variable is zero.

The **vertical intercept** of a curve is the point at which it hits the vertical axis; it shows the value of the *y*-variable when the value of the *x*-variable is zero.

The **slope** of a line or curve is a measure of how steep it is. The slope of a line is measured by "rise over run"—the change in the *y*-variable between two points on the line divided by the change in the *x*-variable between those same two points.

When variables are related this way—that is, when an increase in one variable is associated with an increase in the other variable—the variables are said to have a **positive relationship.** It is illustrated by a curve that slopes upward from left to right. Because this curve is also linear, the relationship between outside temperature and number of sodas sold illustrated by the curve in panel (a) of Figure 2A-2 is a positive linear relationship.

When an increase in one variable is associated with a decrease in the other variable, the two variables are said to have a **negative relationship.** It is illustrated by a curve that slopes downward from left to right, like the curve in panel (b) of Figure 2A-2. Because this curve is also linear, the relationship it depicts is a negative linear relationship. Two variables that might have such a relationship are the outside temperature and the number of hot drinks a vendor can expect to sell at a baseball stadium.

Return for a moment to the curve in panel (a) of Figure 2A-2 and you can see that it hits the horizontal axis at point *B*. This point, known as the **horizontal intercept,** shows the value of the *x*-variable when the value of the *y*-variable is zero. In panel (b) of Figure 2A-2, the curve hits the vertical axis at point *J*. This point, called the **vertical intercept,** indicates the value of the *y*-variable when the value of the *x*-variable is zero.

A Key Concept: The Slope of a Curve

The **slope** of a line or curve is a measure of how steep it is and indicates how sensitive the *y*-variable is to a change in the *x*-variable. In our example of outside temperature and the number of cans of soda a vendor can expect to sell, the slope of the curve would indicate how many more cans of soda the vendor could expect to sell with each 1° increase in temperature. Interpreted this way, the slope gives meaningful information. Even without numbers for *x* and *y*, it is possible to arrive at important conclusions about the relationship between the two variables by examining the slope of a curve at various points.

The Slope of a Linear Curve

Along a linear curve the slope, or steepness, is measured by dividing the "rise" between two points on the curve by the "run" between those same two points. The rise is the amount that *y* changes, and the run is the amount that *x* changes. Here is the formula:

$$\frac{\text{Change in } y}{\text{Change in } x} = \frac{\Delta y}{\Delta x} = \text{Slope}$$

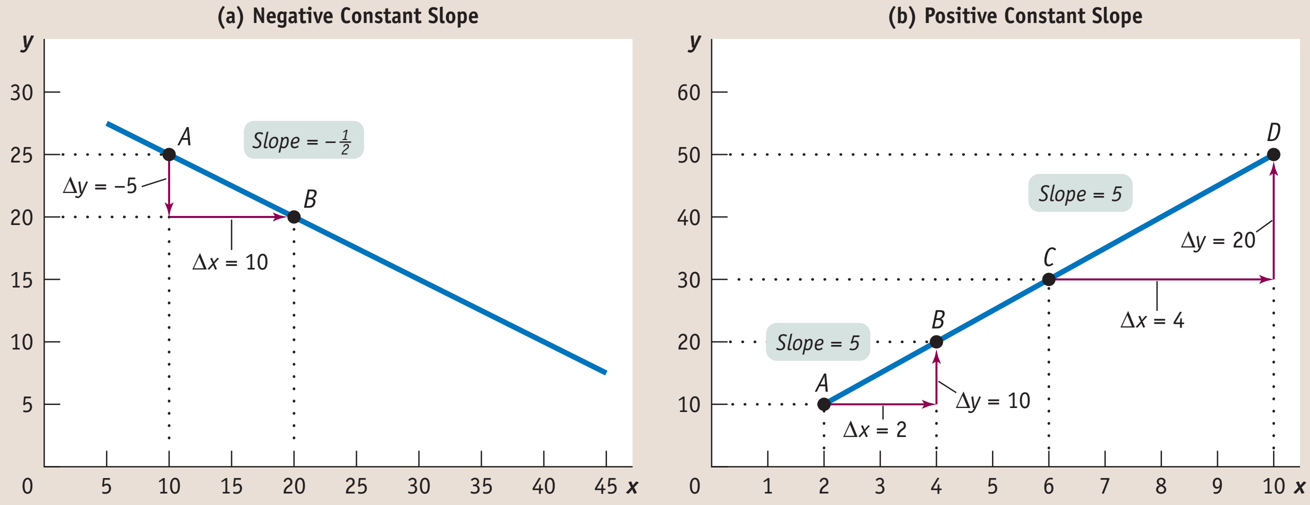
In the formula, the symbol Δ (the Greek uppercase delta) stands for "change in." When a variable increases, the change in that variable is positive; when a variable decreases, the change in that variable is negative.

The slope of a curve is positive when the rise (the change in the *y*-variable) has the same sign as the run (the change in the *x*-variable). That's because when two numbers have the same sign, the ratio of those two numbers is positive. The curve in panel (a) of Figure 2A-2 has a positive slope: along the curve, both the *y*-variable and the *x*-variable increase. The slope of a curve is negative when the rise and the run have different signs. That's because when two numbers have different signs, the ratio of those two numbers is negative. The curve in panel (b) of Figure 2A-2 has a negative slope: along the curve, an increase in the *x*-variable is associated with a decrease in the *y*-variable.

Figure 2A-3 illustrates how to calculate the slope of a linear curve. Let's focus first on panel (a). From point *A* to point *B* the value of the *y*-variable changes from 25 to 20 and the value of the *x*-variable changes from 10 to 20. So the slope of the line between these two points is:

$$\frac{\text{Change in } y}{\text{Change in } x} = \frac{\Delta y}{\Delta x} = \frac{-5}{10} = -\frac{1}{2} = -0.5$$

FIGURE 2A-3 **Calculating the Slope**



Panels (a) and (b) show two linear curves. Between points *A* and *B* on the curve in panel (a), the change in *y* (the rise) is –5 and the change in *x* (the run) is 10. So the slope from *A* to *B* is $\frac{\Delta y}{\Delta x} = \frac{-5}{10} = -\frac{1}{2} = -0.5$, where the negative sign indicates that the curve is downward sloping. In panel (b), the curve has a slope from *A* to *B* of $\frac{\Delta y}{\Delta x} = \frac{10}{2} = 5$. The slope from *C* to *D* is $\frac{\Delta y}{\Delta x} = \frac{20}{4} = 5$. The slope is positive, indicating that the curve is upward sloping. Furthermore, the slope between *A* and *B* is the same as the slope between *C* and *D*, making this a linear curve. The slope of a linear curve is constant: it is the same regardless of where it is calculated along the curve.

Because a straight line is equally steep at all points, the slope of a straight line is the same at all points. In other words, a straight line has a constant slope. You can check this by calculating the slope of the linear curve between points *A* and *B* and between points *C* and *D* in panel (b) of Figure 2A-3.

Between *A* and *B*: $$\frac{\Delta y}{\Delta x} = \frac{10}{2} = 5$$

Between *C* and *D*: $$\frac{\Delta y}{\Delta x} = \frac{20}{4} = 5$$

Horizontal and Vertical Curves and Their Slopes

When a curve is horizontal, the value of the *y*-variable along that curve never changes—it is constant. Everywhere along the curve, the change in *y* is zero. Now, zero divided by any number is zero. So, regardless of the value of the change in *x*, the slope of a horizontal curve is always zero.

If a curve is vertical, the value of the *x*-variable along the curve never changes—it is constant. Everywhere along the curve, the change in *x* is zero. This means that the slope of a vertical line is a ratio with zero in the denominator. A ratio with zero in the denominator is equal to infinity—that is, an infinitely large number. So the slope of a vertical line is equal to infinity.

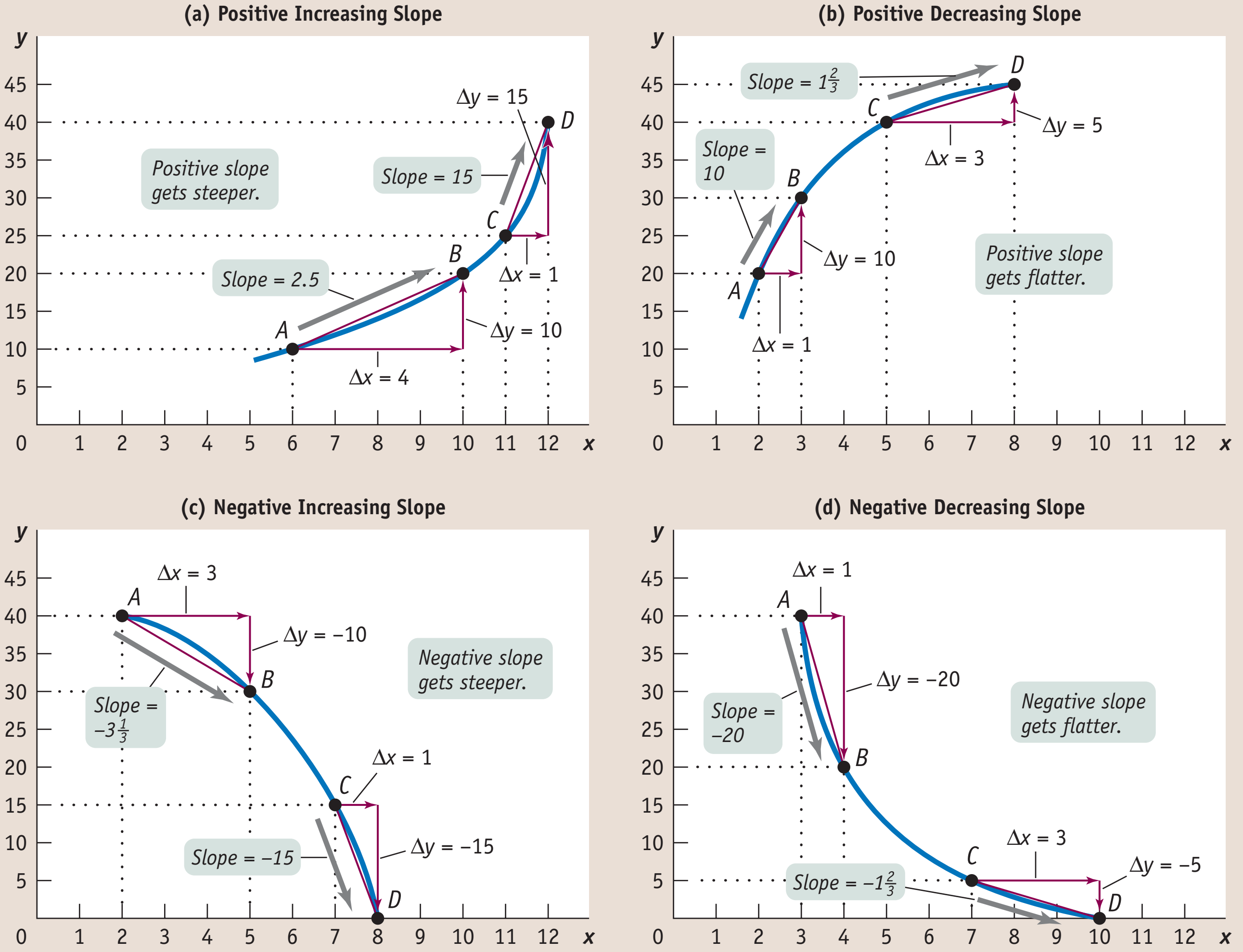
A vertical or a horizontal curve has a special implication: it means that the *x*-variable and the *y*-variable are unrelated. Two variables are unrelated when a change in one variable (the independent variable) has no effect on the other variable (the dependent variable). Or to put it a slightly different way, two variables are unrelated when the dependent variable is constant regardless of the value of the independent variable. If, as is usual, the *y*-variable is the dependent variable, the curve is horizontal. If the dependent variable is the *x*-variable, the curve is vertical.

A **nonlinear curve** is one in which the slope is not the same between every pair of points.

The Slope of a Nonlinear Curve

A **nonlinear curve** is one in which the slope changes as you move along it. Panels (a), (b), (c), and (d) of Figure 2A-4 show various nonlinear curves. Panels (a) and (b) show nonlinear curves whose slopes change as you move along them, but the slopes always remain positive. Although both curves tilt upward, the curve in panel

FIGURE 2A-4 Nonlinear Curves



In panel (a) the slope of the curve from A to B is $\frac{\Delta y}{\Delta x} = \frac{10}{4} = 2.5$, and from C to D it is $\frac{\Delta y}{\Delta x} = \frac{15}{1} = 15$. The slope is positive and increasing; it gets steeper as you move to the right. In panel (b) the slope of the curve from A to B is $\frac{\Delta y}{\Delta x} = \frac{10}{1} = 10$, and from C to D it is $\frac{\Delta y}{\Delta x} = \frac{5}{3} = 1\frac{2}{3}$. The slope is positive and decreasing; it gets flatter as you move to the right. In panel (c) the slope from A to B is $\frac{\Delta y}{\Delta x} = \frac{-10}{3} = -3\frac{1}{3}$, and from C to D it is $\frac{\Delta y}{\Delta x} = \frac{-15}{1} = -15$. The slope is negative and increasing; it gets steeper as you move to the right. And in panel (d) the slope from A to B is $\frac{\Delta y}{\Delta x} = \frac{-20}{1} = -20$, and from C to D it is $\frac{\Delta y}{\Delta x} = \frac{-5}{3} = -1\frac{2}{3}$. The slope is negative and decreasing; it gets flatter as you move to the right. The slope in each case has been calculated by using the arc method—that is, by drawing a straight line connecting two points along a curve. The average slope between those two points is equal to the slope of the straight line between those two points.

(a) gets steeper as you move from left to right in contrast to the curve in panel (b), which gets flatter. A curve that is upward sloping and gets steeper, as in panel (a), is said to have *positive increasing* slope. A curve that is upward sloping but gets flatter, as in panel (b), is said to have *positive decreasing* slope.

When we calculate the slope along these nonlinear curves, we obtain different values for the slope at different points. How the slope changes along the curve determines the curve's shape. For example, in panel (a) of Figure 2A-4, the slope of the curve is a positive number that steadily increases as you move from left to right, whereas in panel (b), the slope is a positive number that steadily decreases.

The slopes of the curves in panels (c) and (d) are negative numbers. Economists often prefer to express a negative number as its **absolute value,** which is the value of the negative number without the minus sign. In general, we denote the absolute value of a number by two parallel bars around the number; for example, the absolute value of –4 is written as $|-4| = 4$. In panel (c), the absolute value of the slope steadily increases as you move from left to right. The curve therefore has *negative increasing* slope. And in panel (d), the absolute value of the slope of the curve steadily decreases along the curve. This curve therefore has *negative decreasing* slope.

The **absolute value** of a negative number is the value of the negative number without the minus sign.

A **tangent line** is a straight line that just touches, or is tangent to, a nonlinear curve at a particular point. The slope of the tangent line is equal to the slope of the nonlinear curve at that point.

Calculating the Slope Along a Nonlinear Curve

We've just seen that along a nonlinear curve, the value of the slope depends on where you are on that curve. So how do you calculate the slope of a nonlinear curve? We will focus on two methods: the *arc method* and the *point method.*

The Arc Method of Calculating the Slope An arc of a curve is some piece or segment of that curve. For example, panel (a) of Figure 2A-4 shows an arc consisting of the segment of the curve between points *A* and *B*. To calculate the slope along a nonlinear curve using the arc method, you draw a straight line between the two end-points of the arc. The slope of that straight line is a measure of the average slope of the curve between those two end-points. You can see from panel (a) of Figure 2A-4 that the straight line drawn between points *A* and *B* increases along the *x*-axis from 6 to 10 (so that $\Delta x = 4$) as it increases along the *y*-axis from 10 to 20 (so that $\Delta y = 10$). Therefore the slope of the straight line connecting points *A* and *B* is:

$$\frac{\Delta y}{\Delta x} = \frac{10}{4} = 2.5$$

This means that the average slope of the curve between points *A* and *B* is 2.5.

Now consider the arc on the same curve between points *C* and *D*. A straight line drawn through these two points increases along the *x*-axis from 11 to 12 ($\Delta x = 1$) as it increases along the *y*-axis from 25 to 40 ($\Delta y = 15$). So the average slope between points *C* and *D* is:

$$\frac{\Delta y}{\Delta x} = \frac{15}{1} = 15$$

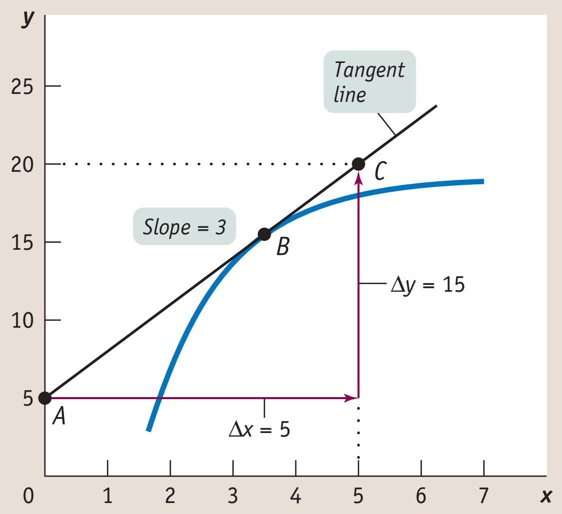
Therefore the average slope between points *C* and *D* is larger than the average slope between points *A* and *B*. These calculations verify what we have already observed—that this upward-tilted curve gets steeper as you move from left to right and therefore has positive increasing slope.

The Point Method of Calculating the Slope The point method calculates the slope of a nonlinear curve at a specific point on that curve. Figure 2A-5 on the next page illustrates how to calculate the slope at point *B* on the curve. First, we draw a straight line that just touches the curve at point *B*. Such a line is called a **tangent line:** the fact that it just touches the curve at point *B* and does not touch the curve at any other point on the curve means that the straight line is *tangent* to the curve at point *B*. The slope of this tangent line is equal to the slope of the nonlinear curve at point *B*.

FIGURE 2A-5

Calculating the Slope Using the Point Method

Here a tangent line has been drawn, a line that just touches the curve at point *B*. The slope of this line is equal to the slope of the curve at point *B*. The slope of the tangent line, measuring from *A* to *C*, is $\frac{\Delta y}{\Delta x} = \frac{15}{5} = 3$.



You can see from Figure 2A-5 how the slope of the tangent line is calculated: from point *A* to point *C*, the change in *y* is 15 and the change in *x* is 5, generating a slope of:

$$\frac{\Delta y}{\Delta x} = \frac{15}{5} = 3$$

By the point method, the slope of the curve at point *B* is equal to 3.

A natural question to ask at this point is how to determine which method to use—the arc method or the point method—in calculating the slope of a nonlinear curve. The answer depends on the curve itself and the data used to construct it. You use the arc method when you don't have enough information to be able to draw a smooth curve. For example, suppose that in panel (a) of Figure 2A-4 you have only the data represented by points *A*, *C*, and *D* and don't have the data represented by point *B* or any of the rest of the curve. Clearly, then, you can't use the point method to calculate the slope at point *B*; you would have to use the arc method to approximate the slope of the curve in this area by drawing a straight line between points *A* and *C*. But if you have sufficient data to draw the smooth curve shown in panel (a) of Figure 2A-4, then you could use the point method to calculate the slope at point *B*—and at every other point along the curve as well.

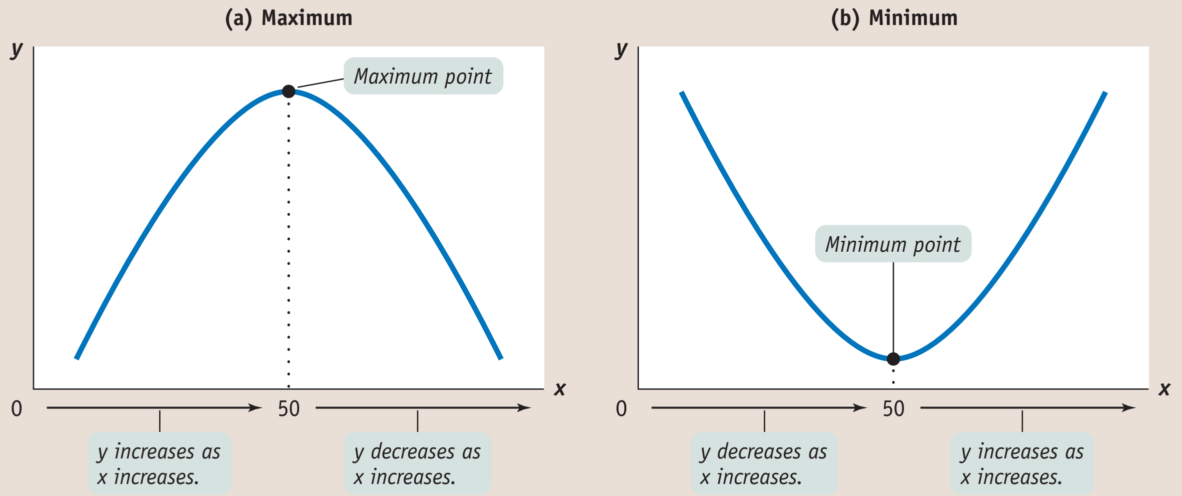
Maximum and Minimum Points

The slope of a nonlinear curve can change from positive to negative or vice versa. When the slope of a curve changes from positive to negative, it creates what is called a *maximum* point of the curve. When the slope of a curve changes from negative to positive, it creates a *minimum* point.

Panel (a) of Figure 2A-6 illustrates a curve in which the slope changes from positive to negative as you move from left to right. When *x* is between 0 and 50, the slope of the curve is positive. At *x* equal to 50, the curve attains its highest point—the largest value of *y* along the curve. This point is called the **maximum** of the curve. When *x* exceeds 50, the slope becomes negative as the curve turns downward. Many important curves in economics, such as the curve that represents how the profit of a firm changes as it produces more output, are hill-shaped like this.

A nonlinear curve may have a **maximum** point, the highest point along the curve. At the maximum, the slope of the curve changes from positive to negative.

FIGURE 2A-6 **Maximum and Minimum Points**



Panel (a) shows a curve with a maximum point, the point at which the slope changes from positive to negative.

Panel (b) shows a curve with a minimum point, the point at which the slope changes from negative to positive.

In contrast, the curve shown in panel (b) of Figure 2A-6 is U-shaped: it has a slope that changes from negative to positive. At x equal to 50, the curve reaches its lowest point—the smallest value of y along the curve. This point is called the **minimum** of the curve. Various important curves in economics, such as the curve that represents how the costs of some firms change as output increases, are U–shaped like this.

Calculating the Area Below or Above a Curve

Sometimes it is useful to be able to measure the size of the area below or above a curve. We will encounter one such case in Chapter 4. To keep things simple, we'll only calculate the area below or above a linear curve.

How large is the shaded area below the linear curve in panel (a) of Figure 2A-7 on the next page? First note that this area has the shape of a right triangle. A right triangle is a triangle that has two sides that make a right angle with each other. We will refer to one of these sides as the *height* of the triangle and the other side as the *base* of the triangle. For our purposes, it doesn't matter which of these two sides we refer to as the base and which as the height. Calculating the area of a right triangle is straightforward: multiply the height of the triangle by the base of the triangle, and divide the result by 2. The height of the triangle in panel (a) of Figure 2A-7 is 10 – 4 = 6. And the base of the triangle is 3 – 0 = 3. So the area of that triangle is

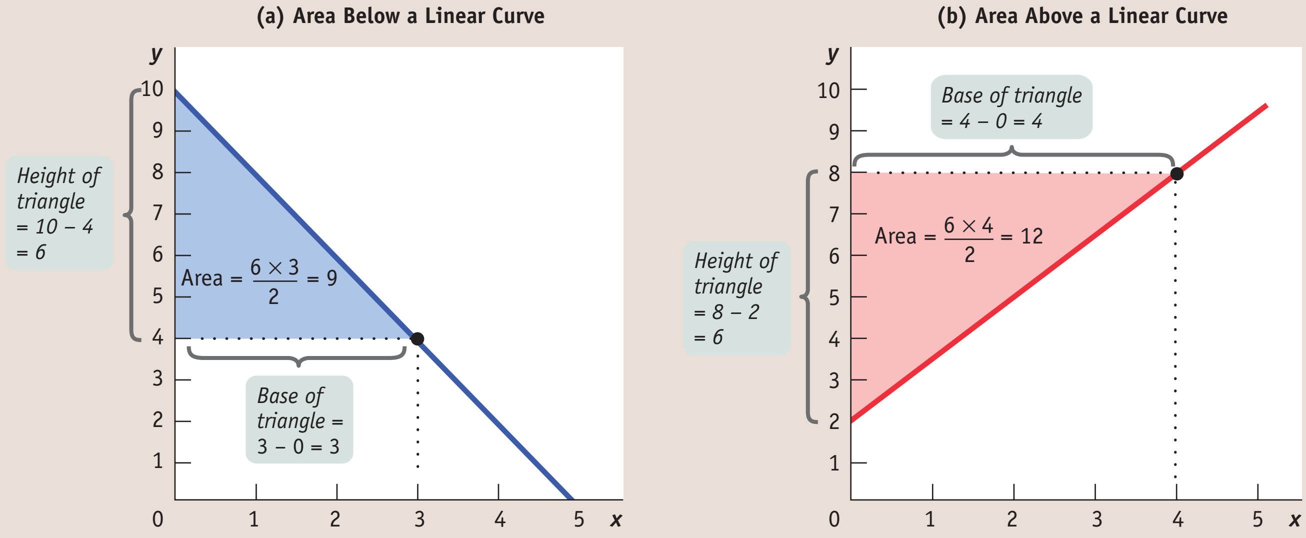
$$\frac{6 \times 3}{2} = 9$$

How about the shaded area above the linear curve in panel (b) of Figure 2A-7? We can use the same formula to calculate the area of this right triangle. The height of the triangle is 8 – 2 = 6. And the base of the triangle is 4 – 0 = 4. So the area of that triangle is

$$\frac{6 \times 4}{2} = 12$$

A nonlinear curve may have a **minimum** point, the lowest point along the curve. At the minimum, the slope of the curve changes from negative to positive.

FIGURE 2A-7 Calculating the Area Below and Above a Linear Curve



The area above or below a linear curve forms a right triangle. The area of a right triangle is calculated by multiplying the height of the triangle by the base of the triangle, and dividing the result by 2. In panel (a) the area of the shaded triangle is $\frac{6 \times 3}{2} = 9$. In panel (b) the area of the shaded triangle is $\frac{6 \times 4}{2} = 12$.

Graphs That Depict Numerical Information

Graphs can also be used as a convenient way to summarize and display data without assuming some underlying causal relationship. Graphs that simply display numerical information are called *numerical graphs*. Here we will consider four types of numerical graphs: *time-series graphs*, *scatter diagrams*, *pie charts*, and *bar graphs*. These are widely used to display real, empirical data about different economic variables because they often help economists and policy makers identify patterns or trends in the economy. But as we will also see, you must be careful not to misinterpret or draw unwarranted conclusions from numerical graphs. That is, you must be aware of both the usefulness and the limitations of numerical graphs.

Types of Numerical Graphs

You have probably seen graphs in newspapers that show what has happened over time to economic variables such as the unemployment rate or stock prices. A **time-series graph** has successive dates on the horizontal axis and the values of a variable that occurred on those dates on the vertical axis. For example, Figure 2A-8 shows the unemployment rate in the United States from 1989 to late 2006. A line connecting the points that correspond to the unemployment rate for each month during those years gives a clear idea of the overall trend in unemployment over these years.

Figure 2A-9 is an example of a different kind of numerical graph. It represents information from a sample of 158 countries on average life expectancy and gross national product (GNP) per capita—a rough measure of a country's standard of living. Each point here indicates an average resident's life expectancy and the log of GNP per capita for a given country. (Economists have found that the log of GNP rather than the simple level of GNP is more closely tied to average life expectancy.)

A **time-series graph** has dates on the horizontal axis and values of a variable that occurred on those dates on the vertical axis.

FIGURE 2A-8

Time-Series Graph

Time-series graphs show successive dates on the *x*-axis and values for a variable on the *y*-axis. This time-series graph shows the seasonally adjusted unemployment rate in the United States from 1989 to late 2006.

Source: Bureau of Labor Statistics.

The points lying in the upper right of the graph, which show combinations of high life expectancy and high log GNP per capita, represent economically advanced countries such as the United States. Points lying in the bottom left of the graph, which show combinations of low life expectancy and low log GNP per capita, represent economically less advanced countries such as Afghanistan and Sierra Leone. The pattern of points indicates that there is a positive relationship between life expectancy and log GNP per capita: on the whole, people live longer in countries with a higher standard of living. This type of graph is called a **scatter diagram,** a 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 curve 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.

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 observed average life expectancy and the log of GNP per capita of a given country for a sample of 158 countries. The upward-sloping fitted line here is the best approximation of the general relationship between the two variables.

Source: Eduard Bos et al., *Health, Nutrition, and Population Indicators: A Statistical Handbook* (Washington, DC: World Bank, 1999).

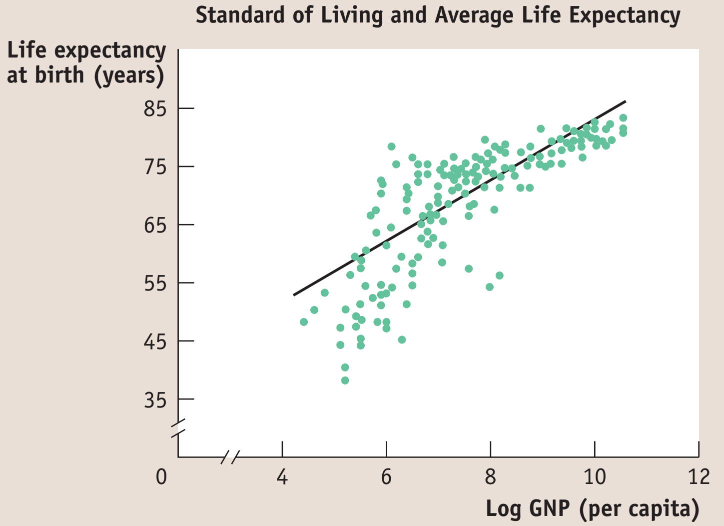


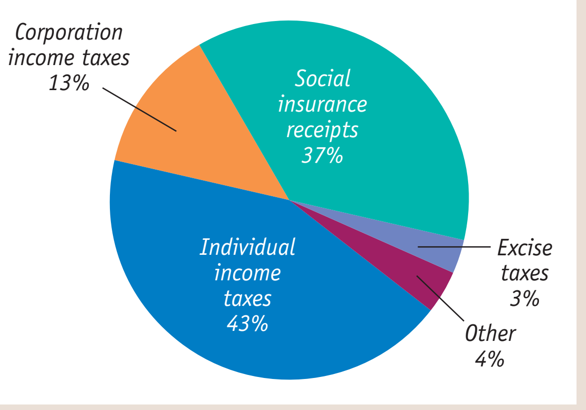
FIGURE 2A-10

Pie Chart

A pie chart shows the percentages of a total amount that can be attributed to various components. This pie chart shows the percentages of total federal revenues that come from each source.

Source: Office of Management and Budget.

Receipts by Source for U.S. Government Budget 2005 (total: $2,153.9 billion)



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 various sources of revenue for the U.S. government budget in 2005, expressed in percentages of the total revenue amount, $2,153.9 billion. As you can see, social insurance receipts (the revenues collected to fund Social Security, Medicare, and unemployment insurance) accounted for 37% of total government revenue and individual income tax receipts accounted for 43%.

Bar graphs use bars of various heights or lengths to indicate values of a variable. In the bar graph in Figure 2A-11, the bars show the percent change in the number of unemployed workers in the United States from 2001 to 2002, separately for White, Black or African-American, and Asian workers. Exact values of the variable that is being measured may be written at the end of the bar, as in this figure. For instance, the number of unemployed Asian workers in the United States increased by 35% between 2001 and 2002. But even without the precise values, comparing the heights or lengths of the bars can give useful insight into the relative magnitudes of the different values of the variable.

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

A **bar graph** uses bars of varying height or length to show the comparative sizes of different observations of a variable.

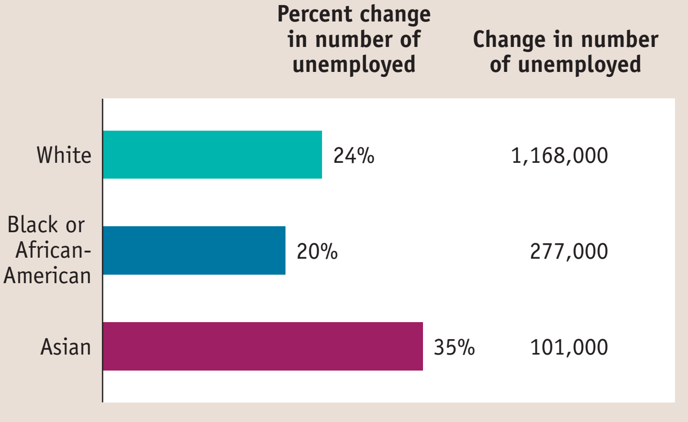
FIGURE 2A-11

Bar Graph

A bar graph measures a variable by using bars of various heights or lengths. This bar graph shows the percent change in the number of unemployed workers between 2001 and 2002, separately for White, Black or African-American, and Asian workers.

Source: Bureau of Labor Statistics.

Changes in the Number of Unemployed by Race (2001–2002)



Problems in Interpreting Numerical Graphs

Although the beginning of this appendix emphasized that graphs are visual images that make ideas or information easier to understand, graphs can be constructed (intentionally or unintentionally) in ways that are misleading and can lead to inaccurate conclusions. This section raises some issues that you should be aware of when you interpret graphs.

An axis is **truncated** when some of the values on the axis are omitted, usually to save space.

Features of Construction Before drawing any conclusions about what a numerical graph implies, you should pay attention to the scale, or size of increments, shown on the axes. Small increments tend to visually exaggerate changes in the variables, whereas large increments tend to visually diminish them. So the scale used in construction of a graph can influence your interpretation of the significance of the changes it illustrates—perhaps in an unwarranted way.

Take, for example, Figure 2A-12, which shows the unemployment rate in the United States in 2002 using a 0.1% scale. You can see that the unemployment rate rose from 5.6% at the beginning of 2002 to 6.0% by the end of the year. Here, the rise of 0.4% in the unemployment rate looks enormous and could lead a policy maker to conclude that it was a relatively significant event. But if you go back and reexamine Figure 2A-8, which shows the unemployment rate in the United States from 1989 to late 2006, you can see that this would be a misguided conclusion. Figure 2A-8 includes the same data shown in Figure 2A-12, but it is constructed with a 1% scale rather than a 0.1% scale. From it you can see that the rise of 0.4% in the unemployment rate during 2002 was, in fact, a relatively insignificant event, at least compared to the rise in unemployment during 1990 or during 2001. This comparison shows that if you are not careful to factor in the choice of scale in interpreting a graph, you can arrive at very different, and possibly misguided, conclusions.

Related to the choice of scale is the use of *truncation* in constructing a graph. An axis is **truncated** when part of the range is omitted. This is indicated by two slashes (//) in the axis near the origin. You can see that the vertical axis of Figure 2A-12 has been truncated—the range of values from 0 to 5.6 has been omitted and a // appears in the axis. Truncation saves space in the presentation of a graph and allows smaller increments to be used in constructing it. As a result, changes in the variable depicted on a graph that has been truncated appear larger compared to a graph that has not been truncated and that uses larger increments.

FIGURE 2A-12

Interpreting Graphs: The Effect of Scale

Some of the same data for the year 2002 used in Figure 2A-8 are represented here, except that here they are shown using 0.1% increments rather than 1% increments. As a result of this change in scale, the rise in the unemployment rate during 2002 looks much larger in this figure compared to Figure 2A-8.

Source: Bureau of Labor Statistics.

An **omitted variable** is an unobserved variable that, through its influence on other variables, creates the erroneous appearance of a direct causal relationship among those variables.

The error of **reverse causality** is committed when the true direction of causality between two variables is reversed.

You must also pay close attention to exactly what a graph is illustrating. For example, in Figure 2A-11, you should recognize that what is being shown here are percentage changes in the number of unemployed, not numerical changes. The unemployment rate for Asian workers increased by the highest percentage, 35% in this example. If you confused numerical changes with percentage changes, you would erroneously conclude that the greatest number of newly unemployed workers were Asian. But, in fact, a correct interpretation of Figure 2A-11 shows that the greatest number of newly unemployed workers were White: the total number of unemployed White workers grew by 1,168,000 workers, which is greater than the increase in the number of unemployed Asian workers, which is 101,000 in this example. Although there was a higher percentage increase in the number of unemployed Asian workers, the number of unemployed Asian workers in the United States in 2001 was much smaller than the number of unemployed White workers, leading to a smaller number of newly unemployed Asian workers than White workers.

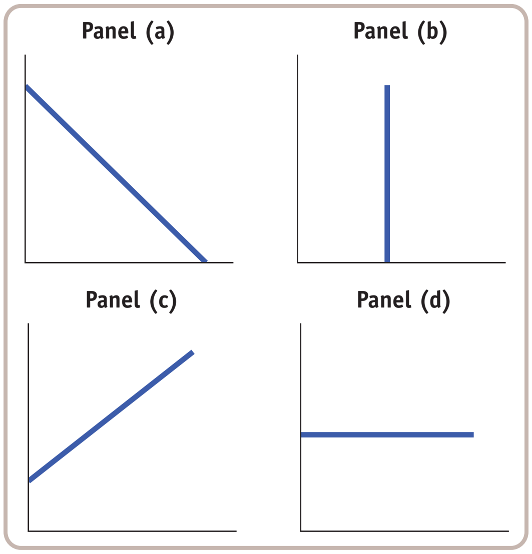
Omitted Variables From a scatter diagram that shows two variables moving either positively or negatively in relation to each other, it is easy to conclude that there is a causal relationship. But relationships between two variables are not always due to direct cause and effect. Quite possibly an observed relationship between two variables is due to the *unobserved* effect of a third variable on each of the other two variables. An unobserved variable that, through its influence on other variables, creates the erroneous appearance of a direct causal relationship among those variables is called an **omitted variable.** For example, in New England, a greater amount of snowfall during a given week will typically cause people to buy more snow shovels. It will also cause people to buy more de-icer fluid. But if you omitted the influence of the snowfall and simply plotted the number of snow shovels sold versus the number of bottles of de-icer fluid sold, you would produce a scatter diagram that showed an upward tilt in the pattern of points, indicating a positive relationship between snow shovels sold and de-icer fluid sold. To attribute a causal relationship between these two variables, however, is misguided; more snow shovels sold do not cause more de-icer fluid to be sold, or vice versa. They move together because they are both influenced by a third, determining, variable—the weekly snowfall, which is the omitted variable in this case. So before assuming that a pattern in a scatter diagram implies a cause-and-effect relationship, it is important to consider whether the pattern is instead the result of an omitted variable. Or to put it succinctly: correlation is not causation.

Reverse Causality Even when you are confident that there is no omitted variable and that there is a causal relationship between two variables shown in a numerical graph, you must also be careful that you don't make the mistake of **reverse causality**—coming to an erroneous conclusion about which is the dependent and which is the independent variable by reversing the true direction of causality between the two variables. For example, imagine a scatter diagram that depicts the grade point averages (GPAs) of 20 of your classmates on one axis and the number of hours that each of them spends studying on the other. A line fitted between the points will probably have a positive slope, showing a positive relationship between GPA and hours of studying. We could reasonably infer that hours spent studying is the independent variable and that GPA is the dependent variable. But you could make the error of reverse causality: you could infer that a high GPA causes a student to study more, whereas a low GPA causes a student to study less.

The significance of understanding how graphs can mislead or be incorrectly interpreted is not purely academic. Policy decisions, business decisions, and political arguments are often based on interpretation of the types of numerical graphs that we've just discussed. Problems of misleading features of construction, omitted variables, and reverse causality can lead to very important and undesirable consequences.

PROBLEMS

1. Study the four accompanying diagrams. Consider the following statements and indicate which diagram matches each statement. Which variable would appear on the horizontal and which on the vertical axis? In each of these statements, is the slope positive, negative, zero, or infinity?



a. If the price of movies increases, fewer consumers go to see movies.

b. More experienced workers typically have higher incomes than less experienced workers.

c. Whatever the temperature outside, Americans consume the same number of hot dogs per day.

d. Consumers buy more frozen yogurt when the price of ice cream goes up.

e. Research finds no relationship between the number of diet books purchased and the number of pounds lost by the average dieter.

f. Regardless of its price, Americans buy the same quantity of salt.

2. During the Reagan administration, economist Arthur Laffer argued in favor of lowering income tax rates in order to increase tax revenues. Like most economists, he believed that at tax rates above a certain level, tax revenue would fall because high taxes would discourage some people from working and that people would refuse to work at all if they received no income after paying taxes. This relationship between tax rates and tax revenue is graphically summarized in what is widely known as the Laffer curve. Plot the Laffer curve relationship assuming that it has the shape of a nonlinear curve. The following questions will help you construct the graph.

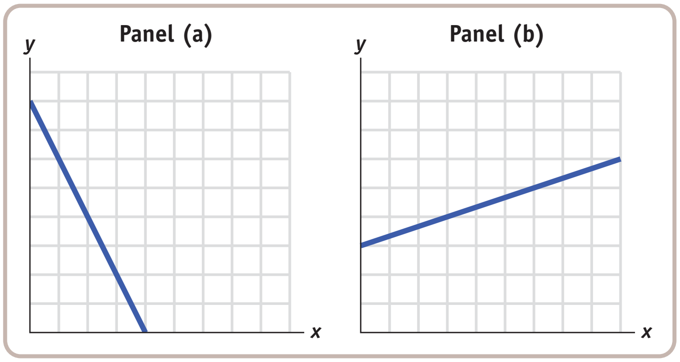
a. Which is the independent variable? Which is the dependent variable? On which axis do you therefore measure the income tax rate? On which axis do you measure income tax revenue?

b. What would tax revenue be at a 0% income tax rate?

c. The maximum possible income tax rate is 100%. What would tax revenue be at a 100% income tax rate?

d. Estimates now show that the maximum point on the Laffer curve is (approximately) at a tax rate of 80%. For tax rates less than 80%, how would you describe the relationship between the tax rate and tax revenue, and how is this relationship reflected in the slope? For tax rates higher than 80%, how would you describe the relationship between the tax rate and tax revenue, and how is this relationship reflected in the slope?

3. In the accompanying figures, the numbers on the axes have been lost. All you know is that the units shown on the vertical axis are the same as the units on the horizontal axis.



a. In panel (a), what is the slope of the line? Show that the slope is constant along the line.

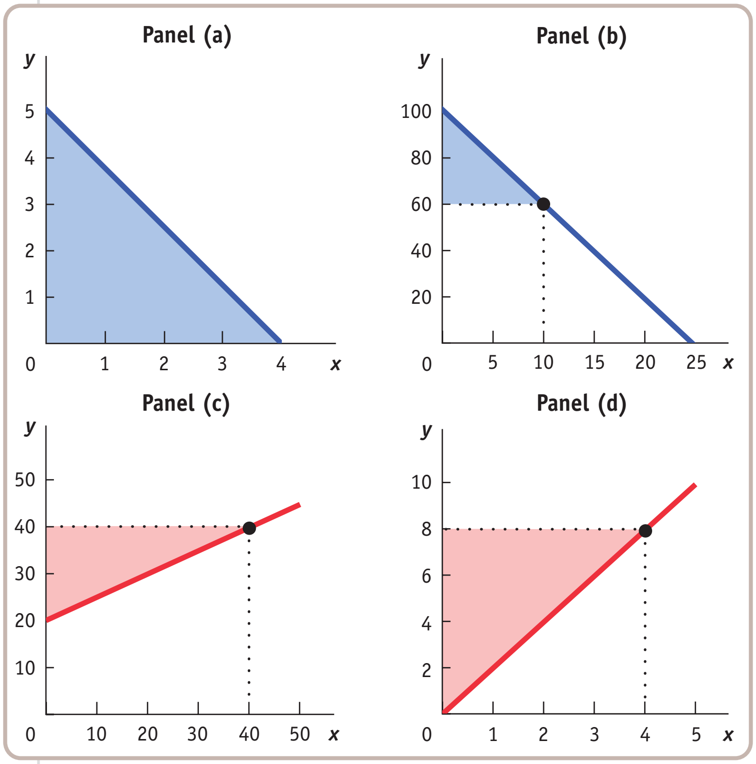
b. In panel (b), what is the slope of the line? Show that the slope is constant along the line.

4. Answer each of the following questions by drawing a schematic diagram.

a. Taking measurements of the slope of a curve at three points farther and farther to the right along the horizontal axis, the slope of the curve changes from –0.3, to –0.8, to –2.5, measured by the point method. Draw a schematic diagram of this curve. How would you describe the relationship illustrated in your diagram?

b. Taking measurements of the slope of a curve at five points farther and farther to the right along the horizontal axis, the slope of the curve changes from 1.5, to 0.5, to 0, to –0.5, to –1.5, measured by the point method. Draw a schematic diagram of this curve. Does it have a maximum or a minimum?

5. For each of the accompanying diagrams, calculate the area of the shaded right triangle.



6. The base of a right triangle is 10, and its area is 20. What is the height of this right triangle?

7. The accompanying table shows the relationship between workers' hours of work per week and their hourly wage rate. Apart from the fact that they receive a different hourly wage rate and work different hours, these five workers are otherwise identical.

Name	Quantity of labor (hours per week)	Wage rate (per hour)
Athena	30	$15
Boris	35	30
Curt	37	45
Diego	36	60
Emily	32	75

a. Which variable is the independent variable? Which is the dependent variable?

b. Draw a scatter diagram illustrating this relationship. Draw a (nonlinear) curve that connects the points. Put the hourly wage rate on the vertical axis.

c. As the wage rate increases from $15 to $30, how does the number of hours worked respond according to the relationship depicted here? What is the average slope of the curve between Athena's and Boris's data points using the arc method?

d. As the wage rate increases from $60 to $75, how does the number of hours worked respond according to the relationship depicted here? What is the average slope of the curve between Diego's and Emily's data points using the arc method?

8. Studies have found a relationship between a country's yearly rate of economic growth and the yearly rate of increase in airborne pollutants. It is believed that a higher rate of economic growth allows a country's residents to have more cars and travel more, thereby releasing more airborne pollutants.

a. Which variable is the independent variable? Which is the dependent variable?

b. Suppose that in the country of Sudland, when the yearly rate of economic growth fell from 3.0% to 1.5%, the yearly rate of increase in airborne pollutants fell from 6% to 5%. What is the average slope of a nonlinear curve between these points using the arc method?

c. Now suppose that when the yearly rate of economic growth rose from 3.5% to 4.5%, the yearly rate of increase in airborne pollutants rose from 5.5% to 7.5%. What is the average slope of a nonlinear curve between these two points using the arc method?

d. How would you describe the relationship between the two variables here?

9. An insurance company has found that the severity of property damage in a fire is positively related to the number of firefighters arriving at the scene.

a. Draw a diagram that depicts this finding with number of firefighters on the horizontal axis and amount of property damage on the vertical axis. What is the argument made by this diagram? Suppose you reverse what is measured on the two axes. What is the argument made then?

b. In order to reduce its payouts to policyholders, should the insurance company therefore ask the city to send fewer firefighters to any fire?

10. The accompanying table illustrates annual salaries and income tax owed by five individuals. Apart from the fact that they receive different salaries and owe different amounts of income tax, these five individuals are otherwise identical.

Name	Annual salary	Annual income tax owed
Susan	$22,000	$3,304
Eduardo	63,000	14,317
John	3,000	454
Camila	94,000	23,927
Peter	37,000	7,020

a. If you were to plot these points on a graph, what would be the average slope of the curve between the points for Eduardo's and Camila's salaries and taxes using the arc method? How would you interpret this value for slope?

b. What is the average slope of the curve between the points for John's and Susan's salaries and taxes using the arc method? How would you interpret that value for slope?

c. What happens to the slope as salary increases? What does this relationship imply about how the level of income taxes affects a person's incentive to earn a higher salary?